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Report to the Congress; by Elmer B. Staats, Comptroller General.

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Authority: Space Act of 1958.

The National Aeronautics and Space Administration (NASA) is constructing space shuttle facilities at Kennedy Space Center (KSC), the primary launch, landing, and orbiter refurbishment site which is scheduled to become operational in mid-1980. A second site, Vandenberg Air Force Base (VAFB), will be funded by the Department of Defense (DOD) and is expected to become operational in June 1983 at a cost of about $1 billion. Findings/Conclusions: The need for new facilities at VAFB is questionable. Proposed facilities at VAFB have been justified primarily on the basis that northerly launches are not permissible from KSC due to the danger of flying over land. DOD officials contended that KSC shuttle launches would not have the capability to handle certain DOD payloads, and the Department of State has expressed a concern about the possibility of adverse Soviet reaction to northerly launches from KSC. These justifications seem to be unwarranted since: land overflight would not be a serious problem with the type of vehicle involved, and the critical phase of the launch would be over ocean; defense and civil missions projected for the 1980's are feasible from KSC; and the KSC delivery capability can be increased to meet future DOD requirements. Congressional inquiry may be needed to determine the seriousness of State's concern. NASA and DOD believe that five orbiters are needed with an investment cost per orbiter of about $600 million to $850 million. If an orbiter fleet of this magnitude were developed, funding might not be available for further scientific payloads. Three orbiters could accommodate a considerable increase in space activity during the next decade and a fourth orbiter could provide for fleet attrition. Recommendations: Unless there are compelling national security reasons, the Congress should not

fund VAFB modifications to accommodate the shuttle. It should fund no more than the four orbiters now under development and production, and NASA's request for Orbiter 104 in the fiscal year 1979 budget should be denied. (BTW)

7226

BY THE COMPTROLLER GENERAL

Report To The Congress

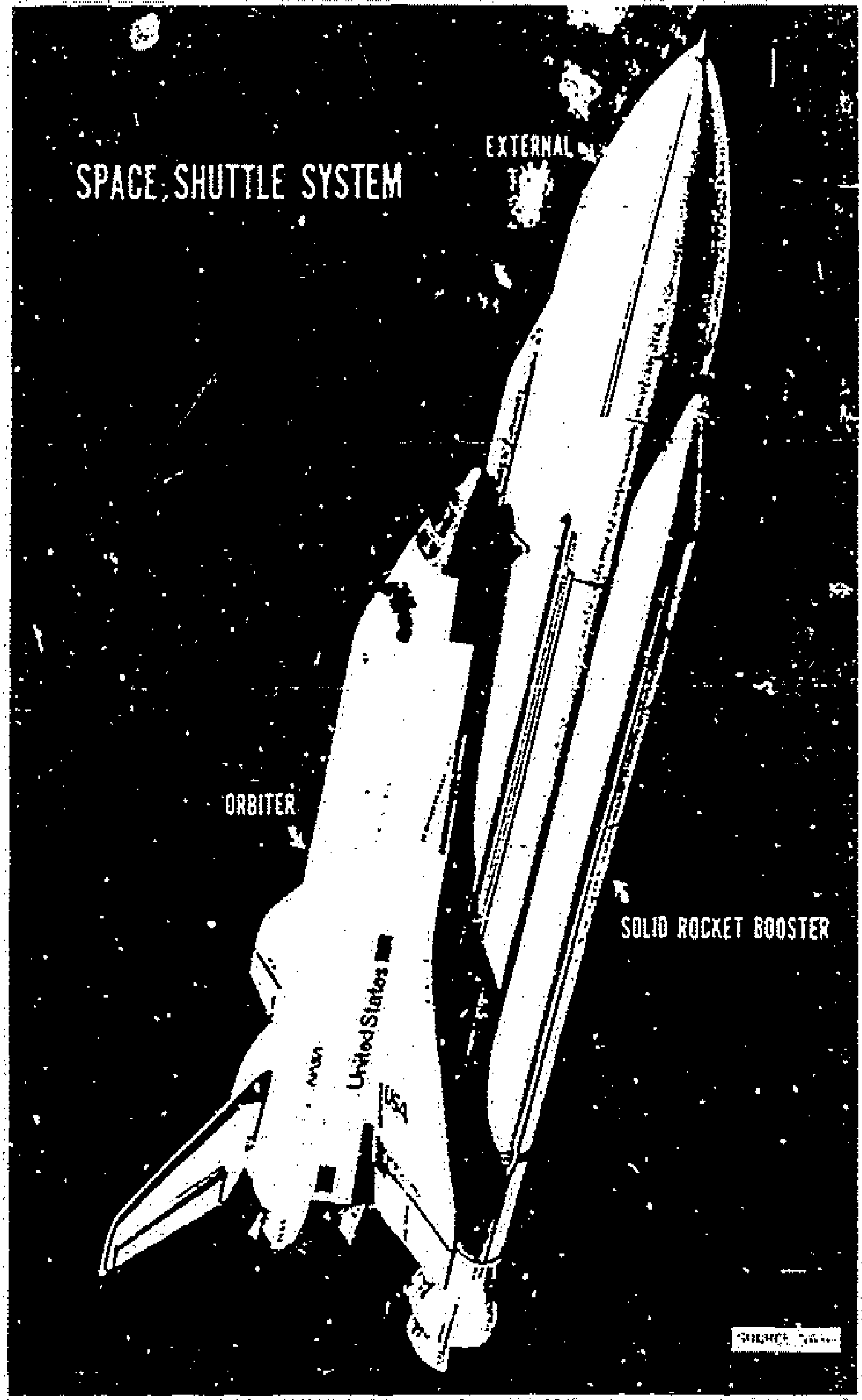
OF THE UNITED STATES

A Second Launch Site For The Shuttle? An Analysis Of Needs For The Nation's Space Program

This report examines the need for two space shuttle launch sites and the number of shuttle orbiters needed to support the Nation's space program during the next decade. Billions of dollars could be saved if planned operations at Vandenberg Air Force Base in California were transferred to Kennedy Space Center in Florida and if fiscal year 1979 funds to start construction of another orbiter were eliminated.

The Congress should not fund the Vandenberg site unless there are compelling national security reasons, nor should it fund more than the four shuttle vehicles presently under development and production.

PSAD-78-57
AUGUST 4, 1978


SPACE SHUTTLE SYSTEM
EXTERNAL
ORBITER
SOLID ROCKET BOOSTER
United States
USA

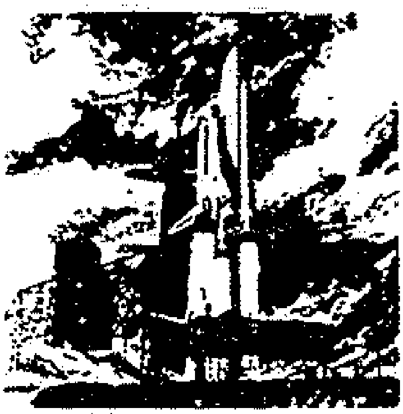
NASA PHOTO

3 EXTERNAL TANK (ETI) SEPARATION

About eight minutes after launch the main engines are shut down. The Orbiter separates from the ET and continues in orbiting to an operational orbit. The nonreusable ET continues around the world in a suborbital trajectory to a predetermined remote ocean area.

2 SRB SEPARATION

After about two minutes the SRBs separate from the Shuttle and are parachuted into the ocean about 145 miles from the launch site. The SRBs will be recovered and reused an estimated 10 times. The main engines continue to provide thrust.



1 LAUNCH

Two solid rocket boosters (SRBsI and the Orbiter's three main engines provide thrust for lift off.

SOURCE: NASA

4 OPERA

The Orb
return
Spacelab

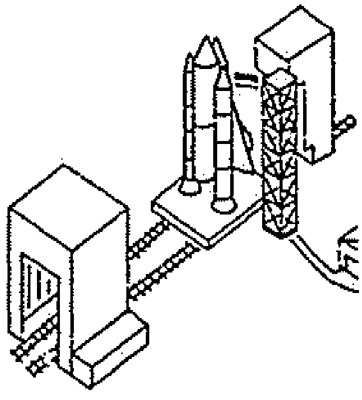
Because
the Orb
for other

The Or
purpose
Orbiter's

SPACE TRANSPORTATION SYSTEM C

- SPACE SHUTTLE
- SPACELAB
- UPPER STAGE PROPULSION UNITS
- GROUND FACILITIES AND SUPPORT

THE TRANSPORTATION COST FOR A STANDARD SH
IS ESTIMATED, BY NASA, TO BE OVER $16 MILLION
BASED ON A 7 PERCENT ANNUAL INFLATION FACT
TO OVER $34 MILLION PER FLIGHT IN REAL YEAR



8 GROUND TURNAROUND OPERATIONS

About two weeks are needed to prepare the Shuttle for another mission. Ground operations include:

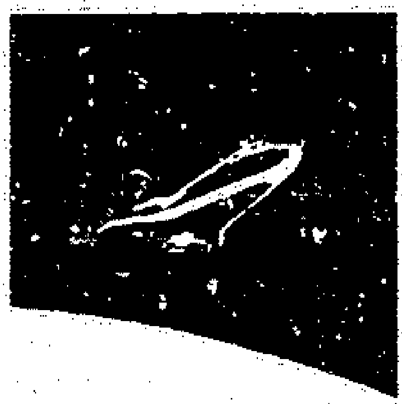
refurbishing the Orbiter,
installing payload(s) in the Orbiter's cargo bay, and
integrating the Orbiter, ET, and SRBs

A[illegible] AND SPACELAB 5

[illegible]ace will be to deliver and [illegible] and provide support for [illegible]

[illegible] require orbits higher than [illegible] upper stages will be used [illegible] orbit

[illegible] th Spacelab, [illegible] remains attached to the [illegible]



6 DE ORBIT

After space operations have been completed, the payload bay doors are closed, and the Orbiter is decelerated and oriented for reentry into the Earth's atmosphere.

7 APPROACH AND LANDING

In an unpowered (deadstick) glide, the Orbiter approaches a predetermined landing runway, which may be at the launch site or one of several contingency landing sites. In the latter case, NASA's modified Boeing 747 will ferry (piggyback) the Orbiter to the launch site.

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

B-18313...

To the President of the Senate and the
Speaker of the House of Representatives

This report questions the need for a space transportation system consisting of two shuttle launch and landing sites and five orbiters. It discusses the potential for accomplishing a balanced and viable space program with a space transportation system consisting of three or four orbiters operating from the Kennedy Space Center launch and landing site at a potential saving of $2.3 billion to $ .5 billion.

This report recommends that, unless there are compelling national security reasons, the Congress not fund modifications to Vandenberg Air Force Base for a west coast shuttle launch and landing site. It recommends also that the Congress provide funds for no more than four orbiters. We testified on March 9, 1978, on the issues discussed in this report before the Subcommittees on Defense, HUD-Independent Agencies, and Military Construction, House Committee on Appropriations.

This review was made as a part of our continuing effort to apprise the Congress of the status of major system acquisitions and to assist it in exercising its legislative and review functions.

We made our review pursuant to the Budget and Accounting Act, 1921 (31 U.S.C. 53), and the Accounting and Auditing Act of 1950 (31 U.S.C. 67).

Copies of this report are being sent to the Director, Office of Management and Budget; the Secretary of Defense; and the Administrator, National Aeronautics and Space Administration.

Elmer B. Staats
Comptroller General
of the United States

COMPTROLLER GENERAL'S
REPORT TO THE CONGRESS

A SECOND LAUNCH SITE FOR THE SHUTTLE? AN ANALYSIS OF NEEDS FOR THE NATION'S SPACE PROGRAM

D I G E S T

The United States could save as much as $2.3 billion to $3.5 billion if it modified its present plan for a space transportation system consisting of two shuttle launch and landing sites and up to five orbiters.

A balanced and viable space program with only three or four orbiters operating from the Kennedy Space Center launch and landing site could achieve this saving. The need for new facilities at Vandenberg Air Force Base is questionable.

The National Aeronautics and Space Administration (NASA) and the Department of Defense (DOD) have taken the position that the program, to be fully operational, would require two launch sites.

GAO feels that a single-site operation would support the Nation's space program and recommends that, unless there are compelling national security reasons, the Congress not fund modifications to Vandenberg Air Force Base for a west coast shuttle launch and landing site and that it provide funds for no more than four orbiters.

The fiscal year 1979 budget cycle will probably determine the full complement of space transportation system facilities and hardware (launch sites and number of orbiters plus options). NASA's budget request includes production funds for a completely new vehicle, Orbiter 104, which will ultimately cost about $852 million. DOD's fiscal year 1979 budget request includes funds to start facility construction at Vandenberg Air Force Base. This facility is scheduled to be operational in June 1983 and will require an investment of about $1 billion, of which about $60 million has been

incurred. About $2.5 billion in manpower costs will be needed to operate the Vandenberg complex through 1992. Thus, the current funding decisions will influence the Nation's space programs during the next decade. Within a given budget, the more funds are allocated to transportation hardware and facilities, the less funds will be available for space science and applications. (See pp. 7 to 10.)

WHY A SECOND LAUNCH SITE?

Proposed space transportation system facilities at Vandenberg Air Force Base have been justified primarily on the basis that northerly launches are not permissible from Kennedy Space Center due to the danger of flying over land. Also DOD officials said that Kennedy shuttle launches would not have the capability to handle certain DOD payloads and that northerly launches from Kennedy could cause an adverse reaction from the Soviet Union. (See p. 11.)

The land overflight constraint seems unwarranted, considering the nature of the shuttle--a partially reusable and man-rated vehicle with commensurate high reliability. Moreover, it should be noted that the most critical phase of a shuttle launch, regardless of launch direction, is between the time of lift-off and separation of the solid rocket boosters. The critical phase or initial ascent of northerly launches from Kennedy will be over 345 miles of ocean between the Center and the coast of South Carolina. (See pp. 11 to 17.)

The principal proponent for the second site is DOD; yet, the military payload model projects an average of only four shuttle launches a year from Vandenberg. All defense and civil missions projected for the 1980s are feasible from Kennedy in terms of orbiter performance and requisite facilities.

DOD believes that one of its space programs, involving two defense satellites a year now projected for the Vandenberg launch, cannot be accommodated from Kennedy because a 32,000-pound delivery capability may be needed.

The Kennedy delivery capability, however, can be increased to meet this DOD requirement by making adjustments to the mission or operating profile as appropriate. Also, because these payloads are still prospective and are not planned for launch until after 1983, it seems preferable to design them specifically for a Kennedy launch. Efforts are underway to improve the weight carrying capability of the shuttle. (See p. 10 and pp. 17 to 19.)

Also, the Department of State has expressed a concern about the possibility of adverse Soviet reaction to northerly launches from Kennedy. Further congressional inquiry may be needed to determine if this concern is serious enough to justify spending up to $3.5 billion to construct and operate a second site. (See pp. 20 to 24.)

ORBITER FLEET SIZE

The investment cost per orbiter is about $600 million to $850 million. NASA and DOD have taken the position that five orbiters are needed. This view is based largely on the national payload mission model put together by NASA, which projects 560 shuttle flights during 1980-91. The mission model is only a planning estimate, and neither the executive branch nor the Congress has set forth specific space objectives for the 1980s. The validity of the 560-flight model as an appropriate national space goal is questionable. (See pp. 25 to 27.)

Possibly the most significant aspect of the present model is Spacelab--almost one-half of the proposed payloads in the model involves this space transportation system element. Whether such extensive manned activity in space is needed, however, is unknown. Such activity is analogous to a permanent space station, and, during the fiscal year 1978 budget process, the Office of Management and Budget recommended that, until the long-range goals and objectives of the U.S. space programs are assessed, funding of space station studies be deferred. (See pp. 27 to 31.)

Space goals should be flexible so that program plans can be adjusted to meet changing fiscal, political, and technical circumstances. Even with an annual sustained budget of $4 billion, NASA would be unable to both finance its mission model payloads and undertake any future major developments. Many scientists are concerned that, after developing and procuring a very ambitious transportation system, NASA would not have substantial funds for further scientific payloads. Procuring too many orbiters would be uneconomical because idle equipment would have to be maintained. More significantly, it could create pressures to utilize the available capacity, perhaps diluting the quality of space endeavors and affecting other national priorities. (See pp. 31 to 33.)

For purposes of policy analysis, space capabilities can be presented in terms of alternative fleet sizes--three and four orbiters.

Considering the substantial capabilities of three orbiters, it is difficult to foresee needs beyond that fleet size. An additional orbiter obviously could provide an increased yearly launch rate of 53 to over 60 a year. The fourth orbiter would also provide a cushion for attrition. The present administration has decided to support a four-orbiter fleet, with consideration for a fifth in future years in the event that projected flight rates or the accidental loss of an orbiter warrant such an action. NASA's procurement strategy to achieve this fleet size position is not completely clear. In essence, four orbiters are already being developed and produced: Orbiters 099; 101, which was used for launch and landing tests; 102; and 103. Yet, NASA's fiscal year 1979 budget request includes funds for a completely new vehicle (Orbiter 104), which is described as the fourth orbiter because NASA does not intend, at this time, to upgrade Orbiter 101 to operational status. Under this plan the optional or future orbiter will be either (1) Orbiter 101, modified for orbital flight capability, or (2) another wholly new vehicle, procured after Orbiter 104. (See pp. 33 to 37.)

RECOMMENDATIONS TO THE CONGRESS

Three or four orbiters operating from one launch site, Kennedy Space Center, can meet the Nation's foreseeable space program needs during the next decade.

GAO believes that, unless there are compelling national security reasons for the west coast space transportation system site, the Congress should not fund Vandenberg Air Force Base modifications to accommodate the shuttle. (See p. 24.)

The Congress should fund no more than the four orbiters now under development and production. Consistent with this position, NASA's request for Orbiter 104 in the fiscal year 1979 budget should be denied. Three orbiters can accommodate a considerable increase in space activity during the next decade; a fourth orbiter would provide for fleet attrition. (See p. 38.)

Contents

ABBREVIATIONS

DOD	Department of Defense
ET	external tank
KSC	Kennedy Space Center
NASA	National Aeronautics and Space Administration
OMB	Office of Management and Budget
SRB	solid rocket booster
STS	space transportation system
VAFB	Vandenberg Air Force Base

<u>GLOSSARY</u>

Abort	Any factor which postpones or prematurely terminates a mission. An abort can arise from a prelaunch or postlaunch decision and can be caused by the environment, any component of the space transportation system, or the payload.
Free-flying satellite	A payload which operates independently once launched into orbit.
Launch azimuth	The initial flight direction of the shuttle. An angle measured from true north to the direction of the ascent ground track of the launch vehicle. For example, a due east launch would have an azimuth of 90 degrees and a due north launch would have an azimuth of 0 degrees.
Low (near) Earth orbit	Orbits in the general range of a few hundred miles above the Earth's surface. The shuttle will normally have an orbital altitude of 160 nautical miles.
Nautical mile	A unit of distance used principally in navigation equal to 1.151 statute miles or 6,080 feet.
Orbit	A closed path under the influence of gravitational or other force.
Orbital inclination	The angle between the plane of an orbit and the Equator. For example, a polar orbit has a 90-degree inclination and an equatorial orbit has a 0-degree inclination.
Payload	A specific complement of instruments, space equipment, and support hardware carried aloft to accomplish a mission or discrete activity in space.
Polar orbit	An orbit which crosses the Earth's poles on every revolution around the Earth. It has a 90-degree orbital inclination.

Real-year dollars	Also known as current dollars, are always associated with the purchasing power of the dollar in the year that the expenditure will occur. When future costs are stated, the figures given are actual amounts which will be paid, including inflation.
Sonic boom	A shock wave created by an aircraft traveling at supersonic speeds. Space shuttle launches and orbiter landings must be constrained so that unacceptable sonic booms will not impinge on populated areas.
Sun-synchronous orbit	An orbit which retains the same Sun-Earth orientation as the Earth moves around the Sun. Practical inclinations are between 96 and 104 degrees, depending on spacecraft altitude.
1971 dollars	The purchasing power of the dollar with 1971 as the base year. Estimates are in base-year dollars when future costs are adjusted to exclude inflation.

CHAPTER 1

THE SHUTTLE IN PERSPECTIVE

Early in 1972 President Richard M. Nixon announced the decision to proceed with development of a new space transportation system (STS) to meet civil and defense needs. The multibillion dollar project would be the largest ongoing research and development work in the United States.

Also in 1972 the two expected principal users, the National Aeronautics and Space Administration (NASA) and the Department of Defense (DOD), agreed that the program, to be fully operational, would require two launch sites--Kennedy Space Center (KSC) in Florida and Vandenberg Air Force Base (VAFB) in California. NASA's plans called for a total of five orbiters, operating interchangeably between the sites.

The program has progressed considerably since 1972. The contractor delivered the first orbiter in September 1976 for approach and landing tests and will deliver a second orbiter in October 1978 for the first orbital flight in 1979. NASA's fiscal year 1978 budget included initial funds for a third orbiter, and its fiscal year 1979 budget request includes production funds for two additional orbiters: the structural test article upgraded to operational status and a completely new vehicle, Orbiter 104. These vehicles will ultimately cost $596.6 million and $851.6 million, respectively. 1/ This will bring the total number of orbiters to five. However, NASA does not plan to refurbish the approach and landing test orbiter as an operational vehicle at this time. This orbiter may be upgraded if future flight rates or the accidental loss of an orbiter warrant such action.

NASA is constructing shuttle facilities at KSC, the primary launch, landing, and orbiter refurbishment site, scheduled to become operational in mid-1980. The second site, VAFB, will be funded by DOD and is expected to become operational in June 1983 at a cost of about $1 billion. DOD's fiscal year 1979 budget request includes a request for funds to begin STS facility construction at VAFB.

The need for the second launch site and for the additional orbiters is an important question with multifaceted considerations, political as well as economical.

1/Unless otherwise stated, costs in this report are expressed in real-year dollars. (See glossary.)

Current funding decisions may well affect the Nation's space program during the next decade, thus the future of the STS is now. To be evaluated fully, the issues perhaps should be viewed in relation to an overview of the Nation's involvement in space.

OVERVIEW OF U.S. SPACE PROGRAM

On October 4, 1957, the Soviet Union successfully launched Sputnik, an unmanned Earth-circling satellite--a pioneer effort in space. Four years later, the Soviet Union put a man into orbit, another first-in-space effort.

These Soviet accomplishments prompted the United States to reassert U.S. preeminence in the scientific and technological fields. The Space Act of July 29, 1958, established NASA, and Federal expenditures for research and development increased about 15 percent annually during the post-Sputnik period. For fiscal years 1959-70, about $40 billion was appropriated for the civilian space program.

The Nation's initial space programs, although highly successful, were competitive, high-cost, catchup operations. Although most unmanned space programs were, and continue to be, justified on the basis of meeting priority requirements cost effectively, the thrust of manned space programs has been to explore man's relation to the space environment. (See fig. 1.) For example:

--The primary goal of the Mercury program was to put man into orbit.

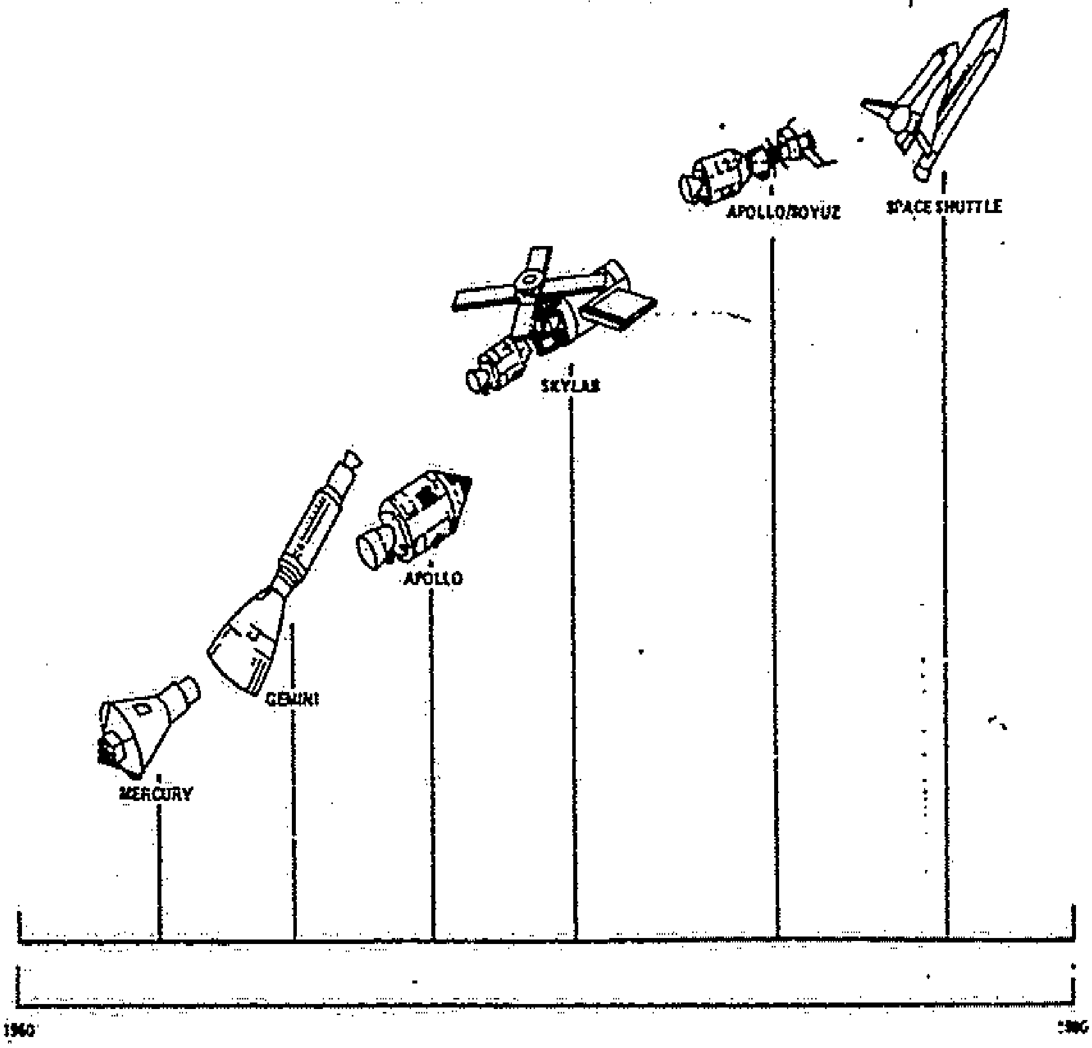
--The Gemini program concentrated on space operations, such as orbital rendezvous maneuvers and extravehicular activities.

--The Apollo program focused on a lunar landing and return. Even though much scientific knowledge was gained, Apollo was primarily a formidable engineering, hardware-building, and training effort, not a scientific investigation program.

--Finally, the initial era of manned space flight essentially ended in the early 1970s with the Skylab program, which was basically a three-man space station to test man's long-duration capabilities in space. The program, first called Apollo Applications Program, initially called for a buildup

FIGURE 1

U.S. MANNED SPACE-FLIGHT OVERVIEW



NOTE: SPACECRAFT ARE NOT DRAWN TO SCALE

SOURCE: NASA

to about 25 flights a year, while preparing to phase in a 12-person space station, but the Skylab program ended after three missions. Between Skylab and STS, there was a one-mission program, Apollo-Soyuz, which was an international linkup in orbit with a manned Russian spacecraft.

The best known of these programs is probably the Apollo project which began in 1961 when President John F. Kennedy proposed that:

"* * * this Nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to earth."

This dramatic proposal is perhaps better viewed in relation to foreign policy than to space science. President Kennedy viewed a lunar landing primarily as a means to enhance the U.S. position in the international political arena. The Presidential goal proved compelling and received strong congressional support as evidenced by massive funding, eventually totaling over $20 billion.

After the manned lunar landing took place on July 20, 1969, the question for policymakers was: "Where shall we go from here?"

EMERGENCE OF STS

In successfully completing Project Apollo, NASA had become heavily invested in manned flight capabilities--especially in terms of physical facilities. For example, three of NASA's major centers were geared almost completely to manned space activities--KSC; Manned Spacecraft Center (now called Johnson Space Center) in Houston, Texas; and Marshall Spaceflight Center in Huntsville, Alabama.

Space policy debates in 1969 were not characterized by a sense of urgency or a crisis like the 1961 setting. The idea of direct competition with the Soviet Union in space spectaculars no longer had popular support. Perhaps due largely to escalating costs of the Vietnam war and to Earth-priority debates which frequently characterized space funding as misguided Government spending, President Lyndon Johnson refused to approve any post-Apollo manned flight programs. In fact, in his last budget, President Johnson specifically left decisions on future manned space activity to the Nixon administration.

It was within this institutional and political setting that NASA proposed a continuing commitment to manned flight activity. NASA sought Presidential approval of a space station, with the space shuttle as a subelement, as the next goal in manned flight. In perspective, it is obvious that the Apollo project greatly influenced discussions of future space goals. For instance, NASA proposed alternatively that a manned expedition to Mars be selected as a post-Apollo goal.

President Nixon was unwilling to commit the Nation to a major new space program, essentially due to budgetary constraints reflecting a restrictive fiscal policy to control inflation. Consequently, NASA's fiscal year 1971 budget was reduced 15 percent from that of 1970. Thus, through the budget process, the space program was reclassified in relation to other national priorities. On March 7, 1970, the President made the following formal statement:

> "Over the last decade, the principal goal of our Nation's space program has been the moon. * * * we must now define new goals which make sense for the seventies. * * * many critical problems here on this planet make high priority demands on our attention and our resources. By no means should we allow our space program to stagnate. But * * * we should not try to do everything at once. Our approach to space must * * * also be balanced."
>
> *   *   *   *   *
>
> "We must also realize that space expenditures must take their proper place within a rigorous system of national priorities. What we do in space from here on in must become a normal and regular part of our national life and must therefore be planned in conjunction with all of the other undertakings which are also important to us."

In view of the President's statement and a reduced budget, NASA had to give up plans to jointly develop a space station and a space shuttle. Of the two, the space station was much further along in design definition; but, without a relatively low-cost transportation system, the entire space budget could be expended on just supplying the station. Hence, a major reversal of priorities took place, and the shuttle emerged as the space program's foremost research and development program for the 1970s and was disassociated from the space station. This required NASA to consider a wholly new

rationale or justification for the shuttle's development on the basis of the shuttle's own merits, rather than its use as a space station supply vehicle.

Detailed planning of the space shuttle had begun in January 1969, when NASA awarded several contracts for feasibility studies. Later that year, after NASA received initial assessments from contractors, it decided on a fully reusable, two-stage shuttle and projected that development costs would be about $5.2 billion (1969 dollars). About a year later, the estimate was revised, almost doubling to about $10 billion (1971 dollars). Concerned about system development costs, the Office of Management and Budget (OMB) asked NASA to conduct a cost-benefit analysis of the shuttle. NASA contracted with Mathematica, Inc., Princeton, New Jersey, to study the relative economic merits of

--the current expendable system, focusing on continued use of the present inventory of expendable launch vehicles;

--a new expendable system, envisaging a new family of expendable vehicles with improved performance; and

--a new space transportation system, using two fully reusable elements--a space shuttle operating between the Earth's surface and low orbits and a space tug providing access from the orbiting shuttle to higher orbits.

Mathematica concluded in its 1971 report that the fully reusable STS configuration would be cost effective if the U.S. space program averaged about 45 flights a year during 1978-90. The issue of whether or not the new STS would actually be cost effective was very controversial and involved arguments too numerous and complex to summarize here. However, it was recognized that (1) any analysis of the shuttle's cost effectiveness could only be, at best, highly speculative and hypothetical and (2) because the cost ranges were so great, economics should not be the primary basis for decision; rather, the decision should focus on the mission and objectives to be achieved. In fact, Mathematica's report emphasized that:

"* * * <u>any investment can only be justified by its goals</u>. This applies to business as well as to government, hence also NASA. A new, reusable Space Transportation System should only be introduced if it can be shown, conclusively, what it is to be used for and that the intended uses are meaningful to those who have to appropriate the funds * * *." (Underscoring supplied.)

Many of the economic justification arguments for the fully reusable STS configuration proved to be somewhat moot. The executive branch and the Congress had doubts about the advisability of the proposed new system. Besides questions about the technical risks associated with pushing the state of the art, there were concerns about the high development costs of a fully reusable system, which would require at least $2 billion (1971 dollars) annually in peak funding years. The administration had indicated a willingness to support a $1 billion (1971 dollars) peak-year funding, which equated to a relatively constant NASA budget of $3.3 billion (1971 dollars) during development years. So, during initial budget sessions for fiscal 1973, OMB, with White House backing, informed NASA that such an advanced, expensive system would not be approved.

This budgetary mandate caused NASA to have contractors research a less costly and more technically feasible configuration. A confusing array of new designs appeared, ranging from an advanced expendable system to a space glider or smaller orbiter. Intense debates and deliberations followed among the President's Office of Science and Technology; congressional committees and members, OMB, NASA, and contractors. These discussions again raised the basic issue of whether or not a shuttle was really needed because there were no specific national space goals for the 1980s or any agreement of what they should be.

The design finally adopted was a compromise, a partially reusable system consisting of a large expendable propellant tank; twin recoverable, solid-fueled rocket boosters; and a manned orbiter vehicle. Mathematica also analyzed the economic merits of this configuration and concluded in January 1972 that the partially reusable shuttle would break even at an annual activity level of about 25 flights. NASA describes Mathematica's analysis as the basic study which established the economic superiority of the shuttle. This configuration was approved for development by the President in January 1972 and by the Congress in March of that same year. The key economic parameters were $5.15 billion (1971 dollars) for development with $1 billion (1971 dollars) annually during peak funding years. Thus, through rigorous, independent oversight procedures, shuttle development costs were cut nearly in half. Explaining the development decision, President Nixon said that "the space shuttle will give us routine access to space by sharply reducing costs in dollars and preparation time."

The fiscal year 1979 congressional funding decisions will probably establish the major operational parameters of the STS in terms of launch sites and the number of orbiters and

Military Uses of Space: 1946-1991

Published by:
Chadwyck-Healey Inc., 1101 King Street, Alexandria, Virginia 22314

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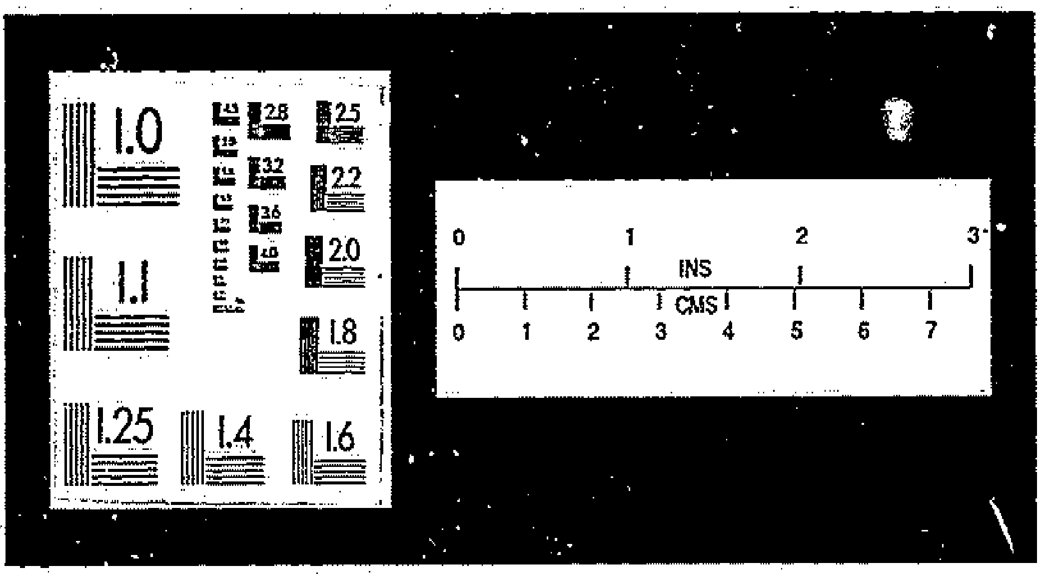

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thereby influence the Nation's space activities during the next decade. DOD has requested funds to begin STS facility construction at VAFB, and NASA has requested funds to start production of another orbiter. After learning that the cost to construct and operate VAFB to serve the DOD and civil polar-launch activities during 1983-92 would be $3.5 billion, we decided to look into this matter and the number of orbiters needed.

The results of our review have been reported informally to appropriate Senate and House subcommittees responsible for NASA and DOD program authorization and appropriations. In addition, our findings were formally presented in testimony on March 9, 1978, before the Subcommittees on Defense, HUD-Independent Agencies, and Military Construction, House Committee on Appropriations.

Our findings on these important issues--the need for a second launch site and the need for more than three orbiters--are discussed in the following chapters.

SCOPE OF REVIEW

We made our review at NASA Headquarters, Washington, D.C.; Johnson Space Center, Texas; Marshall Space Flight Center, Alabama; DOD Headquarters, Washington, D.C.; Vandenberg Air Force Base, California; and the Air Force Space and Missile Systems Organization, El Segundo, California.

In conducting our review, we looked at documents, records, and reports and interviewed officials at Government agencies and contractor organizations. We also discussed program aspects with NASA and DOD officials. We used the technical expertise of a consultant to assist in reviewing the highly technical areas.

We brought our findings to the attention of NASA, DOD, Department of State, and OMB officials. Their comments and observations have been incorporated as appropriate in this report and are included as appendixes VI, VII, VIII, and IX. We have previously issued six reports on STS. (See app. X.)

CHAPTER 2

WHY A SECOND LAUNCH SITE?

The primary launch and landing site, KSC, is planned for shuttle launches to the east and is expected to be operational in 1980. VAFB is scheduled to be operational in June 1983, which represents a 6-month slip due to delays in procurement and availability of orbiters. The VAFB site will handle all polar launches and requires an investment (facilities and related costs) of about $1 billion, of which about $60 million has been incurred. An additional $2.5 billion for manpower costs will be needed to operate the complex through 1992. In our opinion, a single-site STS operation from KSC can save from $2.3 billion to $3.5 billion and provide adequate safeguards to permit northerly launches to polar and near-polar orbits with enough capability to handle all civil and military payloads.

COST ADVANTAGES OF SINGLE-SITE OPERATIONS

Planned facilities and manpower at KSC and VAFB can handle over 40 and 20 shuttle flights a year, respectively. As shown on the following page, a single-site KSC-STS program, at the 60 launches-a-year level, could save the Government at least $2.3 billion.

In our opinion, 40 shuttle launches a year is a more realistic level of activity than 60. (See ch. 3.) Since planned facilities and manpower at KSC can handle over 40 shuttle launches a year, we believe the total cost savings of $3.5 billion can be realized by not modifying VAFB to accommodate shuttle operations and reducing the flight level. We do recognize that some portion of the manpower savings might be realized simply by reducing the currently planned manpower of a two-site operation to support 40 instead of 60 flights a year; however, this cost data was not available at NASA.

Cost Savings of Not Modifying
VAFB to Accommodate Shuttle Operations (note a)

	Facilities	Manpower	Total
		(billions)	
Estimated costs to construct and operate VAFB (note b)	$1.0	$2.5	$3.5
Less additional costs at KSC to support an additional 20 launches (note c)	0.2	1.0	1.2
Cost savings of single-site (KSC) operations	$0.8	$1.5	$2.3

a/See app. II for details.

b/DOD data.

c/Costs shown for increasing the KSC capability from 40 launches to 60 launches a year are based on NASA data.

In responding to our preliminary report, NASA officials said:

"The GAO estimates did not include or properly account for a number of factors which increases both the cost and operational complexity associated with a single shuttle site operation."

However, these factors seem to evolve around NASA's position that shuttle launches to polar orbit from KSC will not be able to accommodate all the DOD payloads. As we show in the following sections, northerly shuttle launches from KSC to polar orbit will have enough capability to handle all DOD and civil payloads.

IS THERE A NEED FOR VAFB?

The principal proponent of the need for STS facilities at VAFB is DOD. Yet, DOD's mission model projects an average of only four shuttle launches a year from VAFB. Approximately six DOD shuttle launches a year are projected from KSC. (See app. I.) Basically, the following statements by DOD's Director of Defense Research and Engineering in 1974 reiterated the official justification for STS facilities at VAFB:

"* * * we propose to add to our Vandenberg Air Force Base complex a shuttle launch capability. This will allow DOD to continue polar launches of payloads from Vandenberg using the shuttle."

*   *   *   *   *

"Once we have met our needs for polar and near polar launches of satellites using the shuttle, this capability would be available for NASA and other civil or international users * * *."

*   *   *   *   *

"Such a capability at Vandenberg is essential * * * since KSC is unacceptable for launching payloads into polar orbits using the shuttle * * *."

DOD's position, as well as that of NASA and the Department of State, is that northerly launches from KSC to polar and near-polar orbits are not acceptable, nor feasible in some cases, because (1) of land overflight of populated areas, (2) of insufficient capability to handle certain defense payloads, and (3) such launches could cause an adverse reaction from the Soviet Union. The following examination of each of these concerns raises the question of whether the large investment in STS facilities at VAFB is justified.

LAND OVERFLIGHT

Historically, to avoid having expendable launch vehicles overfly the continental United States during initial ascent, the U.S. space program has used coastal launch sites. Generally, launches over water are considered relatively safe, but those over land masses purportedly involve more risk.

The most critical phase of a shuttle launch, regardless of launch direction, is between the time of lift-off and the separation of the solid rocket boosters (SRB). An easterly launch, of course, will ascend over the Atlantic Ocean. Similarly, for a northerly KSC launch, the initial ascent is over approximately 345 miles of ocean between KSC and the coast of South Carolina. After the integrated shuttle vehicle ascends from the launch pad, the boosters are jettisoned at an altitude of about 26 miles. At this point, the system has completed the most critical launch phase and is 31 miles down range, over the ocean. (See fig. 2.)

Although there are no official criteria for acceptable risk, the most critical factor involves assessing the statistical probability of mission failure during powered flight; that is, during ascent into orbit. The fact that the shuttle is a manned vehicle with redundant critical systems and intact abort capability suggests a very low probability of failure. During the powered ascent, the shuttle will have an intact abort capability for those selected failures which have the highest probability of occurring. This capability is to provide for the return of the orbiter, crew, and payload safely to the landing site following a mission abort.

Although NASA has not assigned a specific numerical reliability factor to the shuttle, on the basis of extensive knowledge and experience gained from space and aircraft programs, it expects the shuttle to be fully reliable. Contractor studies have continually cited a reliability factor of 0.9999 in risk assessment. Given this degree of reliability, shuttle overflight of land may pose fewer problems than do commercial airlines.

Generally, Air Force range safety personnel evaluate each space flight's acceptability on the basis of such factors as casualty expectations and importance of the payload to national security. According to the Aerospace Corporation, a DOD contractor, launches of expendable vehicles have been permitted with casualty expectations as great as 1 in 12,500; but, more characteristically the acceptable limit has been 1 in 100,000. In comparison, the Aerospace estimate of casualty expectations for a shuttle launched northerly from KSC was 1 in 166,667, which is well within the limits just mentioned. Further, the worldwide casualty expectation associated with random reentry of low orbital debris from a KSC-launched Titan IIIC is 1 in 6,250. Although the cited Titan risks are for debris reentry, whereas the shuttle risks are for launch ascent, the comparison does provide a risk assessment perspective. As shown, the reentry of debris from a Titan launch presents a much greater risk of harming people on the ground than does a shuttle launch. 1/

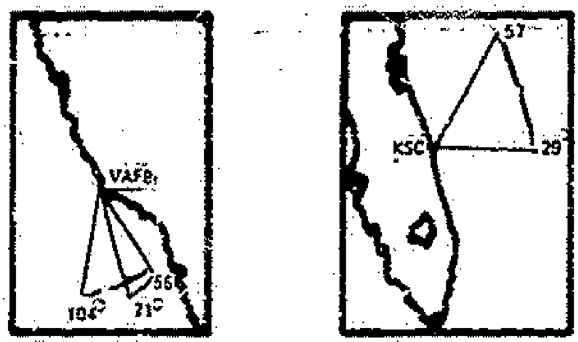
1/DOD said the apparent source of these values was an analysis performed in 1969. However, the casualty expectations for the space shuttle and Titan vehicles were taken from a 1976 and a 1977 study, respectively. In any event, the values are the most current data available.

FIGURE 2

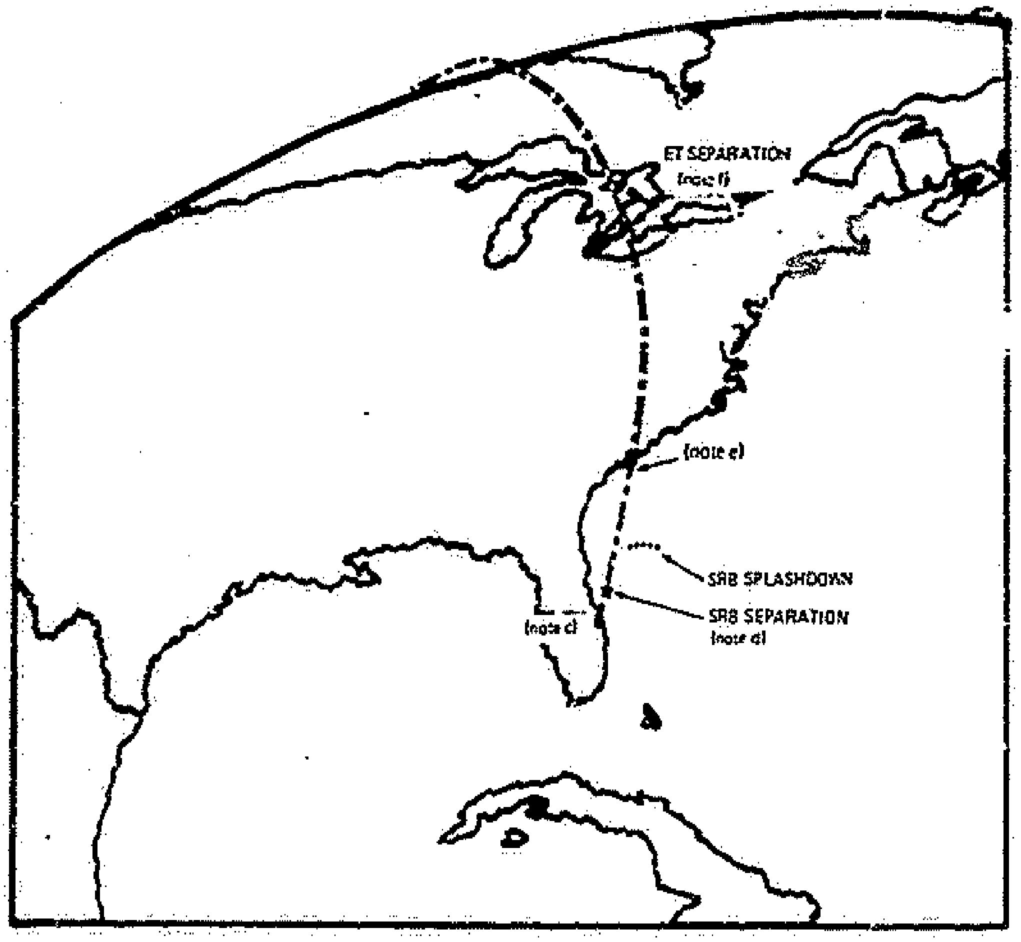
COMPARISON OF STS LAUNCH OPERATIONS:
PLANNED TWO-SITE VS. POSSIBLE ONE-SITE

PLANNED TWO-SITE OPERATIONS (KSC AND VAFB)

CALIFORNIA (note a) FLORIDA (note b)



POSSIBLE ONE-SITE OPERATIONS (KSC ONLY)



NOTES:

[a] Shuttle launches to high inclination orbits (56 to 104 degrees) are planned from VAFB, which is not scheduled for operations until June 1983. Polar (90 degrees) and sunsynchronous (about 98 degrees) orbits are popular high inclination orbits and are especially useful for Earth observation missions. Although present plans show that VAFB will be used to launch the shuttle to inclinations ranging from 56 to 104 degrees, it is probable that sonic boom and external tank (ET) impact considerations will not permit direct shuttle ascent into inclinations of 56 to 71 degrees. If so, a dogleg maneuver (similar to that discussed in note c) will have to be used if these inclinations are to be achieved from VAFB.

[b] The primary site, KSC, is expected to be operational in mid-1980 and will be used to launch the orbiter to low inclination orbits ranging from 28.5 to 57 degrees. According to NASA, inclinations above 57 degrees are not achievable from KSC due to land overflight considerations. However, KSC-only operations are possible (see note c) and offer significant cost savings. For a number of reasons, we feel that an absolute constraint on shuttle overflight of land may be unwarranted.

[c] Southerly launches from KSC are not feasible due primarily to sonic boom considerations. Similarly, for the same reason, plus solid rocket booster splashdown requirements, direct northerly launches from KSC to polar (90 degrees) and near-polar (98 degrees) orbits are not feasible. These orbits are obtainable, however, from KSC by using an initial launch ascent azimuth which is less than true north and then subsequently using a dogleg (orbiter yaw steering) maneuver to change trajectory in flight. This maneuver is done immediately after solid rocket booster (SRB) separation.

[d] About 2 minutes after the integrated shuttle vehicle ascends from the launch pad, the SRBs are jettisoned at an altitude of about 26 miles. The system is 31 miles downrange, over the ocean. At this point the most critical phase of a shuttle launch, regardless of launch direction, has been completed.

[e] After SRB separation, the orbiter and ET continue ascending and are about 70 miles high when they reach the coastline.

[f] The orbiter separates from the ET about 845 miles downrange from the launch site. The orbiter continues into orbit while the ET, in a suborbital trajectory, falls into a remote part of the Indian Ocean.

Actual space shuttle reliability, of course, must be demonstrated. The exact number of shuttle launches required to gain confidence in performance reliability has not been determined. By June 1983, however, when polar shuttle launches are scheduled to begin from VAFB, the STS will have had over 3 years' experience, entailing over 50 shuttle flights. There is some logic in assuming that these flights should provide a sufficient shakedown period in which problems would be identified and corrected. If problems still exist after 3 or 4 years' operations, the entire shuttle program may be in jeopardy. During his March 9, 1978, testimony before three subcommittees of the House Appropriations Committee, the NASA Administrator stated:

> "I think we will have to get through the orbital flight test period before we would have sufficient confidence that we would be through with the expendable launch vehicles."

The test period will consist of six flights. If six shuttle flights provide enough confidence to phase out all expendables, we believe it is reasonable to assume that 50 or more flights should generate enough confidence to permit land overflight.

Moreover, during the few northerly launches which could be required from KSC (about 14 a year), if something major does go wrong (for which there is no intact abort capability), the shuttle system could most likely ditch in the ocean or be blown up 1/, with the pieces falling into the ocean.

NASA officials also state that some northerly launch azimuths being proposed from KSC would cause unacceptable sonic boom overpressures on land and would interfere with oil and gas well activity in the Atlantic Ocean off the coast of Florida.

Sonic boom considerations

During shuttle ascent an intense sonic boom will occur a little over 2 minutes into launch. At this point of a northerly launch, there would be about 40 miles of ocean separating the flight path of the vehicle and the Florida coast. According to estimates presented by NASA in March 1978,

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1/The development flights (first six orbital flights) will carry a set of explosives (flight termination system) on the ET and SRBs. It has not been decided whether such a system will be required for operational flights.

overpressures ranging from 2 pounds per square foot up to about 10 pounds per square foot 1/ may impact a sparsely populated area of the Florida coast. Although the tip of Flagler Beach (1970 population of 1,042) lies near the southern boundary of this area, 2/ the region expected to incur the higher overpressures is a narrow band only about 330 feet wide.

Current sonic boom projections for northerly KSC launches differ significantly from overpressure charts previously developed by NASA. For example, the October 1976 NASA-U.S. Air Force report to OMB indicated that, even for a more northerly launch azimuth, essentially no overpressure would impact on land areas. An earlier report prepared by NASA's Marshall Space Flight Center had reached this same conclusion. Although the Marshall Center's estimate was qualified as being preliminary and awaiting detailed definitions of flight control systems and other variable factors, it was recognized as being representative of the shuttle system, and deviations from the results predicted were expected to be minimal. Moreover, the Center's study was a relatively detailed effort and made use of a sonic boom computer program.

In contrast, the recently supplied data is only a generalized estimate--no detailed study was performed to support it. For example, the assumption was made that the trajectory for a northerly launch azimuth from KSC would not be significantly different than the southerly trajectory from VAFB. The VAFB sonic boom footprint was thus merely overlaid on a Florida coastline map. Scientific reports, however, point

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1/NASA's projection of 10 pounds per square foot near the lateral edge of the sonic boom footprint is a worst-case estimate. It is based on an anticipated focusing effect, the extent of which has never been directly measured in past space vehicle launches.

2/Because behavioral responses to sonic booms depend very largely on individual circumstances, it is difficult to generalize about acceptable levels. For example, overpressures as high as 12 pounds per square foot have been measured in public-viewing areas during firework displays. Structural effects also vary. For example, buildings meeting acceptable construction standards or being in good repair show no damage up to about 20 pounds per square foot. Structures such as windows, plaster, and bric-a-brac, however, may incur some damage with overpressures of about 2 pounds per square foot

out that there is enough difference between northerly and southerly launch trajectories to warrant separate analyses of the sonic boom overpressure footprints. We therefore requested that NASA perform a detailed computer-supported study of the overpressure footprint for a northerly KSC launch azimuth; however, in April 1978, NASA officials stated an analysis was not being performed because it would require an extensive effort for several weeks.

Oil and gas lease considerations

NASA officials are concerned that some northerly shuttle launches from KSC could be constrained by oil and gas lease tracts on the Outer Continental Shelf. Basically, NASA's specific concern involves lease tracts located in waters which are a small portion of the estimated splash-down area for the shuttle's SRBs. About five such tracts were recently sold to commercial interests by the Department of the Interior as part of Outer Continental Shelf sale number 43.

We question whether offshore oil and gas leases would be as constraining against northerly launches as indicated by NASA. If such leases are a constraint, then all easterly launches from KSC may be similarly affected. To explain, another planned sale by the Interior Department, Outer Continental Shelf sale number 54, contains about 160 potential lease tracts which lie in the path of presently planned shuttle launches. Tract identification is continuing, and sales are tentatively scheduled to begin late 1979.

SHUTTLE CAPABILITY FOR NORTHERLY KSC LAUNCHES

A KSC-launched space shuttle can carry over 32,000 pounds into 98-degree inclination orbits, depending on such factors as the orbiter's configuration and operating profile.

A KSC-based STS can accommodate all of the payloads, civil and military, projected for the 1980-91 period, including the missions projected for high inclination orbits. NASA and DOD have, at one time or another, both agreed and disagreed with this position. For example, in February 1978 DOD's position was that, since the shuttle could not carry 32,000 pounds into 98-degree inclination orbits, certain highly classified DOD missions could not be accomplished from KSC because growth versions of current satellites may require up to a 32,000-pound delivery capability. In his February 17, 1978, letter in response to our preliminary report, the Under Secretary of Defense stated:

"The spacecraft which we will launch on the Shuttle from VAFB include our heaviest spacecraft which support missions of highest national priority. These spacecraft flown on the Shuttle will be improved growth versions of operational spacecraft now being launched from VAFB. We now are using the full 24,300 lb TITAN IIID payload delivery capability from VAFB, and are fully depending on the 32,000 lb Shuttle delivery capability from VAFB by the mid-1980s." (Underscoring supplied.)

NASA, DOD, and our Office presented different figures on payload-carrying capability during the March 9, 1978, hearings. The Chairman directed that we get together and reconcile our differences. A meeting was held at Johnson Space Center on March 17, 1978, with headquarters representatives from all agencies present. At this meeting, tentative agreement was reached on the following performance figures arrived at by adjusting the mission or operating profile as appropriate. (See app. III.)

Shuttle Performance Capability for Northerly Launches From KSC (assuming initial launch ascent azimuths of 8, 10, 13, and 19 degrees, with a subsequent dogleg maneuver to obtain a 98-degree, 150-nautical-mile orbit)

	Initial launch ascent azimuth (degrees)			
	8	10	13	19
Weight-carrying capability (pounds)	34,922	33,512	31,148	23,729

These figures do not show the less severe wind conditions that exist at KSC, compared with those at VAFB, which could result in additional performance capability, perhaps ranging from 750 to 2,100 pounds, depending on actual winds at time of launch. Additionally, NASA has underway several studies involving ways to modify the shuttle's design to give additional performance capability ranging from 2,000 to 20,000 pounds. One of the studies involves adding a catalyst to the SRB propellant, which could improve the shuttle's capability by 5,000 pounds.

The performance figures discussed at the March 17 meeting were not derived by making system changes which affect abort procedures, compromise orbiter and crew safety, or

delete items from the standard orbiter delivery configuration even though it was generally recognized that certain nonsafety items (televisions, cameras, etc.) were not mission essential. The participants agreed to discuss at a future meeting those items which possibly could be offloaded, thus giving additional payload capability. Essentially, the only mission restriction relates to not providing for retrieval of another satellite during the same flight that DOD's heaviest payload is delivered into space. This adjustment increases the shuttle's deployment capability because payload weight can be substituted for the fuel that would have been necessary for retrieval operations.

We met again with NASA and DOD representatives on March 23 and 24, 1978, in Washington, D.C. There was no indication at that meeting that substantative changes would be made to the payload-carrying capability tentatively agreed to a week earlier at Johnson Space Center. The DOD representative stated, however, that the payload question was still being studied while we met.

We met again with NASA officials in Washington on March 29; DOD representatives were not present. At this meeting, NASA representatives said that DOD had refigured its mission requirements (i.e., capability needed for its heaviest payloads) and thus several thousand pounds of payload capability should be deducted from the figures tentatively agreed upon earlier. It seems that what NASA was saying was that DOD's payload could be greater than the 32,000-pound requirement previously cited.

It should be emphasized, however, that the designs and weights of these few DOD satellites are not firmly established and they are not scheduled for shuttle launch for another 6 years. Therefore, if the Congress approves these satellites, it seems not only plausible but also highly desirable to design them specifically for launch from KSC.

During the March 29 meeting, NASA's Associate Administrator for Space Transportation Systems commented that the hazards of land overflight was the real issue regarding northerly launches from KSC. He said potential constraints due to sonic boom considerations or oil and gas leases could be overcome. He added that, if for some reason the total performance capability was not enough for DOD's heavy payloads, sufficient system improvements could be made at an additional cost. The Associate Administrator said that, assuming land overflight was acceptable, it would be more cost effective than building shuttle facilities at VAFB.

POSSIBLE SOVIET REACTION

The Department of State, at our request, reviewed the foreign policy implications of high inclination launches from KSC. The Department concluded that such launches would be unacceptable. Perhaps the most important concern voiced by the Department was:

> "Polar launches from KSC would require passage over the USSR on the initial portion of the first orbit. The 1971 Agreement on Measures to Reduce the Risk of Outbreak of Nuclear War between the United States of America and the Union of Soviet Socialist Republics anticipates the need for notification in situations where unidentified objects on early warning systems raise the risk of nuclear war; but we have no knowledge of whether such notification, even if given in timely fashion, would avert Soviet reaction to the sudden appearance of the STS, including its separated external tank."

The Department's concern is how the Soviet Union will react to the orbiter and ET coming over the North Pole's horizon. Specifically, the Department feels that, because the Arctic area is of special strategic importance in terms of nuclear missile targeting, northerly shuttle launches could perhaps be misconstrued.

Although the Arctic area is undoubtedly of strategic importance and sensitivity, interference with early-warning systems may be somewhat of an ambiguous concern. The orbiter and ET will obviously be picked up on Soviet radar. It should be noted that the ET is much larger than a missile. The dimensions of the shuttle's ET in comparison to silo-based missiles are as follows:

	Length	Diameter
	(feet)	
ET	154.0	28.6
Titan II	103.0	10.0
Minuteman III	59.3	6.0
Minuteman II	57.6	6.0

We question whether the risk of misinterpretation is serious enough to justify spending up to $3.5 billion to construct and operate a second STS site. It is to be noted that there may be no essential difference between a high inclination KSC launch and some of the presently planned low inclination launches. To illustrate, for KSC-planned launches to 57

degrees inclination orbits, the separated ET will pass over the Black Sea, several Soviet Bloc countries, and the edge of Russia. (See fig. 3.)

It may also be that space programs and other technological developments since the 1950s have lessened the sensitivity of the Arctic area. Now, submarine-launched ballistic missiles can be fired by either the United States or the Soviet Union from near the other's coasts or from unknown spots in distant oceans. On March 9, 1978, during testimony before the subcommittees of the House Appropriations Committee, the Under Secretary of Defense stated:

> "A fundamental point from the Defense Department's point of view is that during the last decade we have made a very significant commitment to space; we have been gradually transferring important missions in defense to space systems, and during the next decade we plan to continue that.
>
> "As a consequence, we have a major dependence today in the fields of * * * ballistic missile warning systems. More and more the capability in Defense to perform those functions is dependent on space."

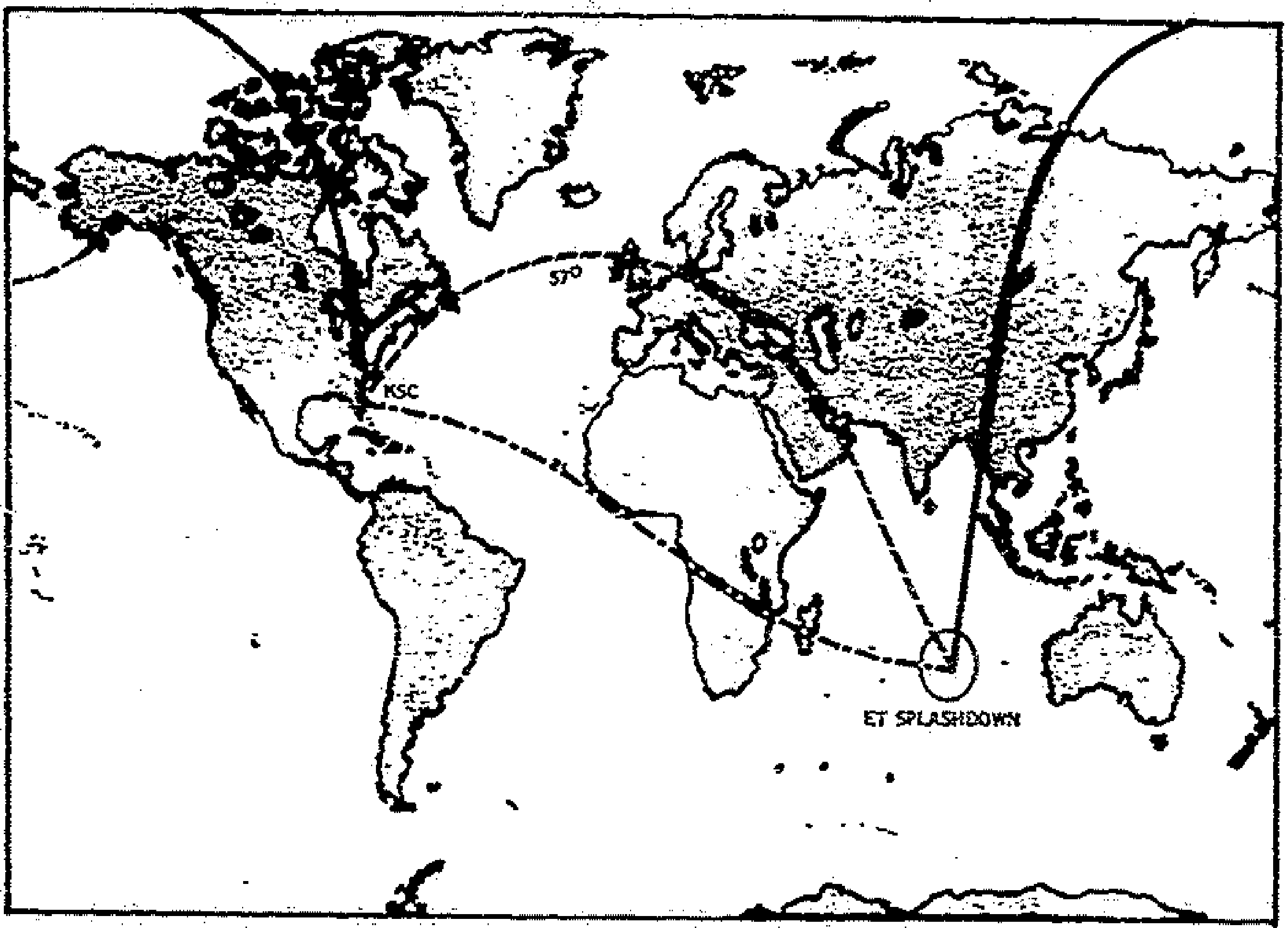
Given space technology of over-the-horizon radar, we question whether northerly shuttle launches from KSC will present sudden appearance problems.

Although any factor which contributes to the possibility of nuclear war should never be treated lightly, the shuttle is an international program of cooperation and will be even more so during the operational phase. If high inclination KSC launches do raise a radar misinterpretation issue, we feel that resolution efforts through multilateral cooperation should be exhausted before spending large amounts of money on VAFB. The 1971 U.S.-Soviet agreement mentioned by the State Department, which calls for prior notification procedures, seems very applicable to the present issue. Since all shuttle launches will be announced beforehand, a step necessary to clear ships from ocean areas where SRBs will splash down, there would seem to be ample time for notifying the proper Soviet authorities as called for in the agreement, especially since there are only about 14 high inclination missions a year.

State Department representatives have also commented that launching north from KSC would be inconsistent with the spirit and intent of the 1971 Agreement on Measures to Reduce the

FIGURE 3

EXTERNAL TANK FLIGHT PATHS FOR KSC LAUNCHES TO INCLINATIONS OF 28.5, 57, AND 98 DEGREES



A 28.5 degree inclination flight path is over the South Atlantic Ocean, and some African countries.

A 57 degree inclination flight path is over the North Atlantic Ocean, parts of Europe including some Communist Bloc countries, part of the USSR, and some Middle East countries.

A 98 degree inclination flight path is over the eastern United States, parts of Canada, the USSR, and China.

Source: NASA

Risk of Outbreak of Nuclear War between the United States of America and the Union of Soviet Socialist Republics. It seems to us that a northerly shuttle launch from KSC is the type of situation anticipated by the 1971 agreement, which established notification procedures. Moreover, the STS program will involve many cooperative space endeavors. The United States and the Soviet Union are presently discussing prospects for joint shuttle missions.

Another reason given by the State Department for its position was:

> "Launching of STS in the direction of populated areas could be expected to bring shuttle more centrally into international debate, especially in the United Nations Outer Space Committee. This would abet arguments raised by countries opposed to our position on such issues as the delimitation or boundary of outer space."

Regarding this concern over international debate, it is probably inevitable that the shuttle will eventually be the focus of discussions on the extent of sovereign airspace, because such issues are not associated simply with high inclination launches from KSC. The presently planned easterly or low inclination launches from KSC pose similar questions for land areas such as Africa, Europe, the Middle East, a portion of Russia, and Soviet Bloc countries--as the ET completes its suborbital flight and comes down in the Indian Ocean. Additionally, the orbiter's atmospheric reentry and landing approach after each mission may focus the issue. State officials responded, however, that the airspace and/or outer space boundary issue is a very low priority item on the agenda of the United Nations Outer Space Committee.

We think the concern about possible international debate over delimiting outer space may not be a substantive reason for precluding northerly launches from KSC. Although there is no international law definition (e.g., multinational signatories to a treaty or other international convention) of outer space, there is a working definition. The United States, the Soviet Union, and most other countries have worked under the assumption that outer space extends to Earth at least as close as the lowest possible orbit. Additionally, in most discussions on the extent of sovereign airspace, about 60 to 65 miles has generally been the upper limit. The separated ET's passage over the Soviet Union would be higher than 65 miles. According to NASA, during a normal high inclination KSC flight, the ET, after separating from the orbiter over the Great Lakes region at an altitude of about

70 miles, would continue halfway around the world and splash down in the Indian Ocean. Before splash down occurred, the ET would have passed over part of the Soviet Union, but at an altitude of no less than 80 miles.

CONCLUSIONS

Single-site STS operations at KSC offer a potential cost saving of $2.3 billion to $3.5 billion. Proposed STS facilities at VAFB have been justified primarily on the basis that high inclination launches are not permissible from KSC due to land overflight considerations. However, the initial (most critical) phase of the shuttle's launch will be over water. The land overflight constraint also seems unwarranted given the nature of the shuttle--a manned vehicle, with commensurate high reliability--and the 3 years' launch activity projected from KSC before high inclination launches are scheduled from VAFB.

The principal proponent of the need for the second site is DOD, yet the military payload model projects an average of only four shuttle launches a year from VAFB. DOD believes that certain of these satellites cannot be launched from KSC because a 32,000-pound or higher delivery capability may be needed. We believe the shuttle's payload delivery capability from KSC is sufficient to handle all defense and civil missions projected for the 1980s in terms of orbiter performance as well as requisite facilities. Also, because the DOD payloads are still prospective and are not planned for launch until after 1983, it seems preferable to design them specifically for KSC launch.

The Department of State, after reviewing the foreign policy implications of high inclination launches from KSC, listed several reasons why such launches would be unacceptable. These reasons, for the most part, were the same as those cited by NASA and DOD. However, one reason--the possibility of adverse Soviet reaction--may warrant further congressional inquiry. Constructive, adversarial inquiry should help resolve the VAFB issue by focusing perceptions of national security interests and providing a healthy test of policy options.

RECOMMENDATION TO THE CONGRESS

Unless there are compelling national security reasons for the west coast STS site, the Congress should not fund VAFB modifications to accommodate the shuttle.

CHAPTER 3

ORBITER FLEET SIZE

The question of whether more than three space shuttle orbiters are needed raises important budgetary and policy issues. The high investment cost per orbiter, about $600 million to $850 million (see app. V), requires a utilization rate which is both intensive and, more importantly, reflective of the Nation's needs. A three-orbiter fleet will not only satisfy current levels of space activity but also provide enough capacity to accommodate substantial increases.

Although the administration takes the position of requesting four orbiters, both NASA and DOD have taken the position that five orbiters are required. The need for five orbiters is based largely on the national payload mission model put together by NASA. This model estimated 1,019 shuttle payloads from mid-1980 through 1991. According to NASA, 560 shuttle flights are required to handle these payloads, and, in turn, five orbiters are needed to perform the 560 launches over the approximate 12-year period. (See app. I.) In essence, then, the five-orbiter position is only as credible as is the payload mission model. 1/

MISSION MODEL ANALYSIS

Essentially, the mission model is only a planning estimate based more on shuttle capability than on approved payload plans. In fact, NASA officials have stated that the mission model is not to be considered as firm space requirements.

Despite this, the mission model has been used to justify the shuttle program--not only the development decision but also the position on orbiter fleet size. The initial payload

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1/ This report treats the 560 flights/1,019 payloads as being the current mission model. The model was slightly revised in October 1977 but was not available to us until after the President's budget submission in January 1978. However, the revisions were quantitatively minor (the model now shows 552 flights/928 payloads for the shuttle) and should not significantly affect our analyses. NASA has also developed a 487-flight model rather than 552 because 487 flights allow for attrition of one orbiter from a 5-orbiter fleet; i.e., a 4-orbiter fleet.

model was developed by NASA in 1971 and served to size the shuttle and test various design and operational considerations. Leading to the 1972 shuttle development decision, the 1971 mission model was used to evaluate STS (a reusable launch system), compared with continued use of the then-current inventory of expendable launch vehicles. In comparison, STS appeared cost effective and flexible, perhaps disproportionately so, because the payload mission model was developed to complement specific shuttle capabilities.

Since 1971 the model has been revised several times. The 1972 revision called for 581 shuttle flights, the 1973 model reflected a dramatic increase to 725 flights, and in 1975 the model projected 572 shuttle flights. The current model, the 1976 revision, reflects 560 flights and is statistically interesting:

--Although NASA has historically launched an average of only 15 payloads a year, this model projects an average launch rate of 45 NASA payloads annually, a threefold increase.

--Although DOD payloads have historically comprised over half the Nation's space activity, defense traffic in this projection is less than one-fourth of the total.

--U.S. commercial and foreign firms are projected to increase their space activity fourfold, from 5 payloads annually to 21.

The model was used in the basic fleet size study, "Joint NASA/USAF Study on Space Shuttle Orbiter Procurement and Related Issues," dated October 15, 1976. The objective of the study, requested by OMB, was to provide the comprehensive data and analyses necessary to determine the number of orbiters needed for the national operational fleet. Even though this study examined various fleet size models (three, four, and five orbiters), each of the models was analyzed in relation to a constant--the projection of 1,019 shuttle payloads for the 1980-91 period. Thus, in large measure, the value of the study is directly dependent on the validity of the projected missions. Because this number of payloads represents a threefold increase in space activity and no specific space objectives for the 1980s have been set forth by either the executive branch or the Congress, the validity of the 560-flight model as an appropriate national space goal is questionable. Possibly the most important aspect of the present mission

model is Spacelab. 1/ Almost one-half of the proposed payloads in the model involves this STS element.

Spacelab considerations

Spacelab directly influences the orbiter fleet size issue from two aspects.

--First, the projected number of launches is significant in itself (20 per year dedicated only to Spacelab activities).

--Second, the duration (7 to 30 days) of Spacelab flights affects orbiter availability for other missions, most of which require only 2 or 3 days from lift-off to return.

Some observers feel that such extensive use of the orbiter for Spacelab missions is a misuse of a transportation vehicle. Basically, given the projected missions (number and duration), Spacelab is equivalent to a permanent presence in space. Indeed, the shuttle Spacelab itself will include many of the characteristics of an early space station. In this light, the proposed level of Spacelab activity probably should be evaluated against the criteria used for space station proposals.

Some insight into the need for a space station is given by considering the experience of an early proposal--DOD's Manned Orbiting Laboratory, which was canceled in June 1969 after more than $1 billion had been spent on the project. In explaining why this space station project was terminated, DOD stressed, among other reasons, that automated systems could perform the functions planned for the Manned Orbiting Laboratory.

1/The Spacelab is basically a general-purpose, orbiting laboratory for manned and automated research activities in near-Earth orbit. Spacelab, unlike the earlier Skylab, will remain attached to the launch vehicle at all times during the mission. The Spacelab consists of module and pallet sections used in various configurations to suit the needs of a particular mission. The pressurized module, accessible from the orbiter cabin through a transfer tunnel, provides a shirt-sleeve working environment. Pallets accommodate experiment equipment for direct exposure to space. (See fig. 4.)

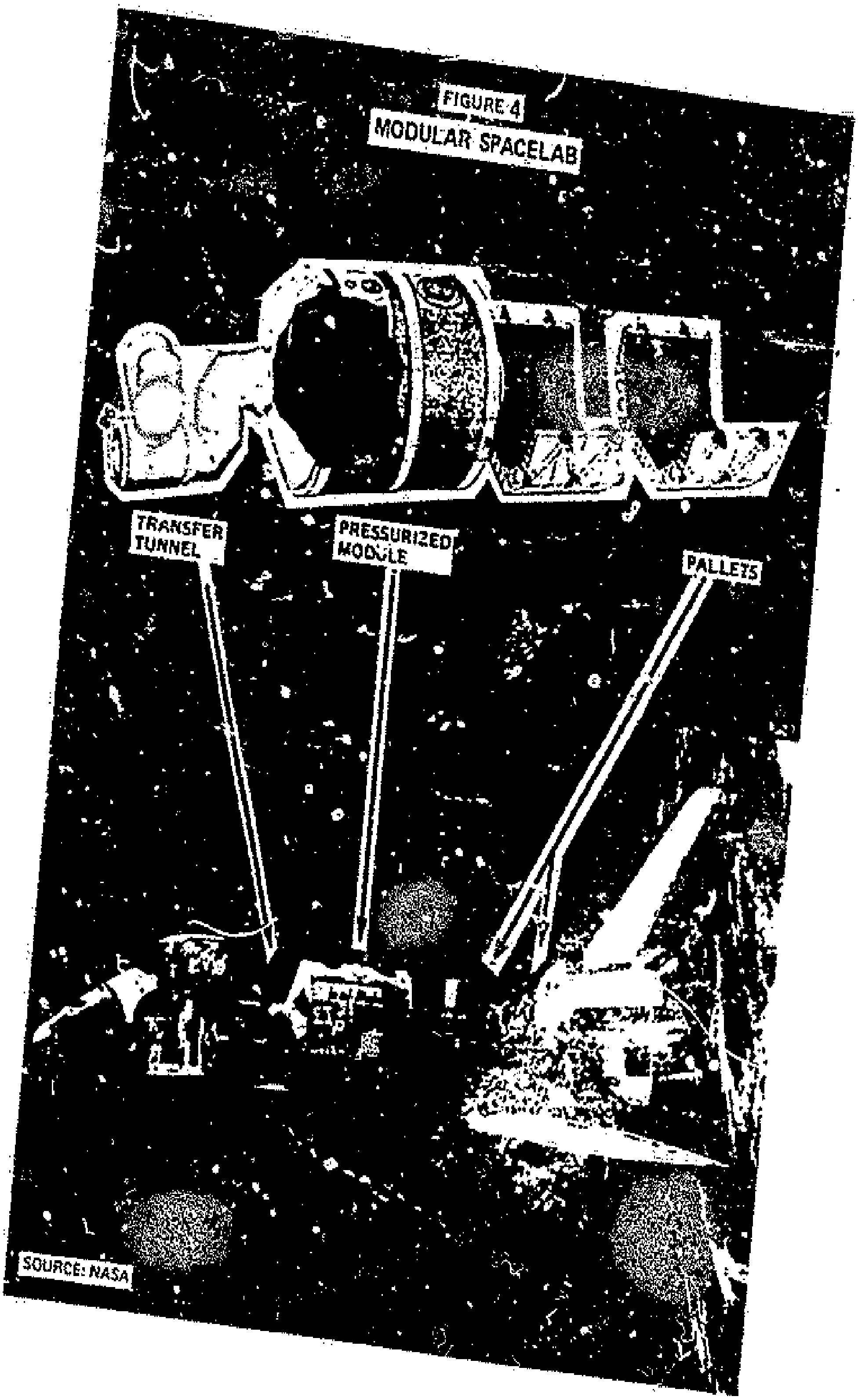

FIGURE 4
MODULAR SPACELAB

More recent insight into the need for a space station is given by "Issues '78," an OMB publication. Commenting on a $15 million line item (representing studies related to a possible future manned Earth-orbiting space station) in NASA's fiscal year 1978 budget request, the issue paper recommended deferral because:

"* * * An orbital space station would represent a major budgetary and policy commitment for the U.S. space program following the completion of space shuttle development. * * * a decision on whether and when to consider the development of a manned orbiting space station would need to address a broad range of issues, including:

" * * * long-range goals and objectives of the U.S. civilian space and aeronautics programs * * *."

Nevertheless, NASA contends that space stations are a logical intermediate step toward the long-range goal of manned planetary exploration and is already advocating development of an orbiting space station for operation in the mid-1980s.

Because Spacelab is such a substantial part of the mission model, we solicited comments from approximately 70 leaders, principally academicians and researchers, in the space sciences community regarding this planned STS usage. As a prefatory comment, several respondents stressed they were presenting

--general comments or impressions because they perhaps were not fully aware of the overall support picture and

--personal views, not those of any organization to which they belonged.

With these qualifications in mind, the following extracted comments are examples of the replies received.

"My overall impression of the STS economic studies is that estimated traffic has been unrealistically high."

"I greatly fear the pressure to make many (Spacelab) flights to prove the 'economy' of (Spacelab) will submerge the basic science program of the space agency."

"I certainly am concerned with the question of the practical number of spacelab flights which can be mounted, especially in view of the budget which NASA will have for science now and in the foreseeable future. * * * such a program is not practical under present ceilings."

Comments regarding the scientific opportunities offered by Spacelab were surprisingly diverse. Some were favorable:

" * * * Is spacelab useful for astrophysics? My answer is decidely yes."

" * * * I don't consider 7 flights per year devoted to astrophysics at all excessive."

"A mission duration one to four weeks would be adequate for most planetary investigations * * *."

"Since spacelab will presumably serve a national cross-section * * *, the flight frequency of 20 per year may be reasonable."

Others were unfavorable or critical:

"There are two primary limitations of Spacelab. One is that only near-earth orbits are accessible and the second is that 7-day missions offer a very low scientific return on investment of time and manpower for most missions."

"I believe that Spacelab missions as described will be of limited value to space physics * * *."

"Spacelab will not replace * * * free flying satellites for magnetospheric or solar terrestrial physics."

"* * * 7 - to 30-days mission lifetime for Spacelab is a severe limitation for many scientific missions. The launch of long-lifetime free-flying satellites from Shuttle will often offer a better opportunity."

Finally, in our opinion, the most appropriate summary comments we received were:

"The Shuttle will be an extremely capable and technologically advanced vehicle, and it will clearly establish the U.S. as having an unmatched capability to operate in space. * * * However,

the extensive use of such a large system will present some problems. The proposed Shuttle launch rates involve launch co ts alone that are far in excess of those of recent years. Further, the projected number of flights will carry total payloads far in excess of those flown in the past. It will surely require greatly increased funding to develop well conceived payloads to make use of all this capability."

These summary comments are very similar to those presented earlier by the National Academy of Sciences. In its 1974 report, "Scientific Uses of the Space Shuttle," the Academy stated:

"The S ... be an important asset to scientific research in and beyond the 1980's."

* * * * *

"The overall scale of Shuttle space science and the proportions of Shuttle opportunities that will go to various scientific disciplines can only be established when a realistic model of Shuttle operations becomes clearer. This model will, of course, depend very much on the funding available for space science and applications during and following the development of the Shuttle."

Budget considerations

Since the United States began its space program in 1958, there have been more space projects feasible than fundable. The extent of STS traffic during the next decade depends largely on congressional willingness to fund space projects and applications, because most payloads (as many as 80 percent) will require Government appropriations. For NASA's projections of federally funded space activity to materialize, over $53 billion 1/ will be required for STS transportation and payload costs. (See app. IV.) It is helpful to keep in mind that all Federal agencies are subject to

---

1/ This figure does not include development and procurement costs for DOD's 193 shuttle payloads because of the data's sensitivity.

varying budgetary ceilings reflective of changes in national priorities and the state of the economy. Frequently, particularly during fiscal crunch periods, space programs have been visible targets for cost reduction. Therefore, space goals should be flexible so that program plans can be adjusted to meet changing fiscal, political, and technical circumstances.

These considerations, in terms of budget flexibility, are very relevant to funding STS operations. Budget flexibility is, to some extent, a function of investment in hardware such as orbiters. Acquiring too few orbiters and related support equipment could place undue constraints on the numbers and types of useful space exploration and applications programs. However, given a finite budget for space activity, the more funds are allocated to investment in orbiters, the less funds will be available to plan, design, and develop useful space payloads and programs during early years of shuttle operations as well as later on. Procuring too many orbiters would be uneconomical because idle equipment would have to be maintained. More significantly, it could create pressures to use the available capacity, perhaps diluting the quality of space endeavors and affecting other national priorities.

Budget flexibility may also be viewed in relation to NASA's basic areas of responsibility to explore space, exploit space, and develop the hardware necessary to explore and exploit space. To date, hardware research and development programs to permit exploration activities, such as Apollo, have most frequently characterized NASA's efforts. Presently, shuttle development takes the major portion of NASA's approximately $4 billion annual budget. When STS begins operations, NASA has estimated that the mission model can be accomplished with a "moderately increasing" budget. Without addressing the accuracy of this estimate, it should be noted that no agency can be guaranteed a constant budget, much less an increasing one. The agency's current spending level, therefore, is not considered an unexaminable base; existing activities are closely scrutinized along with proposed new starts.

Even with an annual sustained budget of $4 billion, NASA would be unable to both finance its mission model payloads and undertake any future major development, such as

--developing a heavy-lift launch vehicle 1/ (up to $12 billion),

---

1/ NASA has contracted a study of a vehicle that could be used to launch payloads larger and heavier than the shuttle could carry. The shuttle may be technically incapable of handling certain prospective space projects involving huge payload masses (and costs), such as deploying an orbiting solar power generating system (over $60 billion).

--constructing a 6-to-12-person space station ($3 billion to $5 billion),

--developing and operating an orbital transfer vehicle to extend manned operations to higher orbits (over $1 billion), or even

--upgrading the shuttle's present configuration (over $1 billion). 1/

ALTERNATIVE LEVELS OF SPACE ACTIVITY

Irrespective of flight rates and orbiter fleet size, STS is structured to be a national program meeting civil and defense needs. The program probably could not be justified by NASA or DOD alone. For purposes of policy analysis, space capabilities can be presented in terms of alternative fleet sizes--three and four orbiters compared to a five-orbiter fleet discussed earlier.

Three-orbiter fleet

Congressional budget office criticism of NASA's mission model prompted the space agency in March 1977 to study reduced launch programs; the lowest program studied was 300 shuttle flights during 1980-92. NASA's study concluded that, even though three orbiters could support this level of activity, five orbiters would still be the most economical fleet size. Five orbiters are more economical than three, according to NASA, because a considerable number of expendable launch vehicles would be needed to back up and to supplement a three-orbiter fleet. We question the validity of this conclusion because three orbiters would be supporting only 100 flights per orbiter, whereas the five orbiters were to have supported 112 flights under the 560-flight mission model. In addition, the orbiter fleet, no matter what size, will provide more responsive backup than existing expendable launch vehicles upon which the Nation is currently relying. Moreover, as explained below, three orbiters can support a representative national space program. It is not economical to buy unneeded capacity.

1/NASA's original goal was to have a fully reusable launch vehicle. The shuttle's present configuration is only a partially reusable system and represents a first-generation vehicle as a replacement for expendable launch vehicles. NASA has ongoing studies of ways to upgrade the shuttle. Candidates being studied to improve the twin rocket boosters include (1) modifying the boosters' air frames and using liquid propellant and (2) developing a cruise-back booster permitting land recovery. Either alternative would cost about $1.4 billion.

Three orbiters may be more than enough to provide a balanced and viable space program, and, indeed, even a program which is a substantial increase over past activity. For instance, the capacity of the two development orbiters alone is enough to fly more payloads than have been launched over the past 10 years. In justifying development of STS, NASA claimed in 1972 that three orbiters were adequate to perform a 581-flight mission model but that two additional orbiters were needed to provide flexibility.

On the basis of NASA estimates of average mission duration and on such performance goals as ground turnaround time between missions, three orbiters could conceivably sustain over 50 launches a year. However, recent NASA and DOD studies project that a three-orbiter fleet can accommodate about 40 launches annually. The lower launch rate resulted because the studies assumed the ground turnaround time between missions would be 200 hours and 240 hours at KSC and VAFB, respectively, rather than the goals of 160 hours and 200 hours. Also, various mission-constraining anomalies, such as weather delays and payload malfunctions, were considered in the launch rate analyses. The recent studies further assumed that each orbiter would be down for a 90-day overhaul period every third year. Such extensive overhaul downtime is not consistent with NASA's plan to maintain/overhaul the orbiters on a continuous basis; that is, as part of the normal ground turnaround operations.

Even the more conservative of these annual launch rates, 40, is an increase over present and past levels of about 25 expendable launch vehicle flights a year. A more realistic way to view the increase in space activity is to look at the projected number of payloads. The orbiter's large cargo bay (15 feet by 60 feet) offers a significant payload-carrying capability, compared with expendable launch vehicles. To illustrate, NASA describes a shuttle launch as being able to replace four Delta or two Atlas-Centaur vehicles, the primary launch vehicles used presently. Assuming only 2 payloads per flight, 3 orbiters could launch 80 payloads a year, which is a doubling of the Nation's past activity. Furthermore, the payload-to-launch ratio will undoubtedly improve as new concepts evolve to exploit STS capabilities. The shuttle provides a great deal of capability and capacity not yet fully understood; the study of cargo integration is only starting. Cargo integration presents formidable technical and managerial problems but has the potential of high payoff in terms of optimizing shuttle payload operations.

The shuttle's capabilities, compared to present launch vehicles' capabilities, can also be discussed in terms of mission modes. Two examples are the Spacelab, discussed

earlier, and the Long Duration Exposure Facility. 1/ Both modes provide an opportunity to perform multiple experiments with a single flight. For example, the first Spacelab mission will carry up to 42 experiments--an activity level which might have required several expendable launch vehicles. Similarly, the Long Duration Exposure Facility can hold 76 experiment trays, with each tray having up to 6 experiments. Such missions will require much support activity. For instance, it has been estimated that for each Spacelab flight 10 or more onground basic research activities are required to develop well-planned experiments. After the flight, data analyses periods may typically be 6 months to 1 year.

Four-orbiter fleet

An additional orbiter obviously could provide an increased yearly launch rate--the total ranging from 53 to over 60 a year. The fourth orbiter would also provide a cushion for attrition--a subject difficult to assess conclusively. NASA believes there will be no attrition. The technical design objectives call for each orbiter to perform 500 missions and have a minimum of 10 years' use. Nevertheless, NASA added that, although quantitative analysis may indicate infinitesimal probabilities of orbiter loss, the shuttle program must endure the same development risk uncertainty during its early flights as that facing any technically complex program, no matter how carefully conceived.

The present administration has decided to support a four-orbiter fleet, with consideration for a fifth in future years in the event that projected flight rates or the accidental loss of an orbiter warrant such an action. 2/ NASA's procurement strategy to achieve this fleet size position is not completely clear. The first vehicle (Orbiter 101) was delivered in 1976 and has been used for approach and landing tests. Orbiter 102's delivery is timed to meet orbital flight tests scheduled in 1979. Fabrication and assembly of Orbiter 103 is continuing as is work begun in fiscal 1978 to configure the Structural Test Article (Orbiter 099) to orbital flight capability. In essence, four orbiters are already being developed and produced. Yet, NASA's fiscal year 1979

1/The Long Duration Exposure Facility is a 30-foot-long, free-flying structure which is delivered by the shuttle to Earth orbit, left for 6 months or more to perform experiments, and then retrieved. (See fig. 5.)

2/"The Budget of the United States Government, Fiscal Year 1979--Appendix," p. 788.

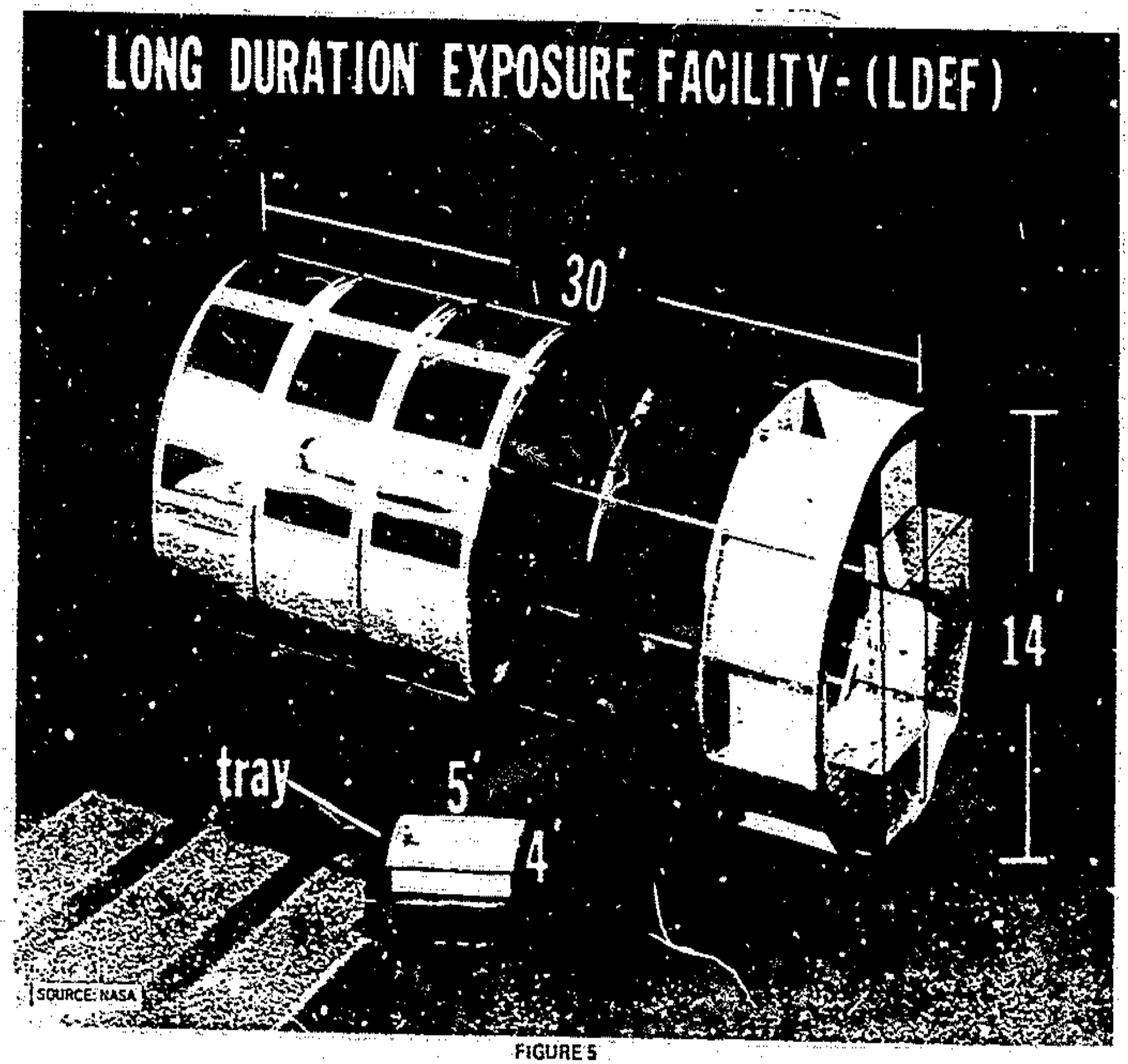
LONG DURATION EXPOSURE FACILITY - (LDEF)
30'
14'
tray
5'
4'
SOURCE: NASA

FIGURE 5

budget request includes funds for a completely new vehicle (Orbiter 104), which is described as the fourth orbiter. Under this plan the optional or future orbiter will be either (1) Orbiter 101, modified for orbital flight capability or (2) another wholly new vehicle. (For more detail on orbiter procurement strategy, see app. V.)

CONCLUSIONS

Although the ultimate worth of the space shuttle is impossible to estimate, the program will obviously have a significant impact on all space activity during the next decade. Some viewers assert that over the long term the shuttle offers definite advantages but that its immediate impact and economic justification depend on the scope of the still undefined national space program; that is, heavy traffic (launch rate) makes the shuttle more attractive. In contrast, other viewers claim that manned space flight is not economical; if justifiable at all, the STS should be regarded as an investment in expanded capability rather than lowered cost.

It may be proper to view STS simply as a first step leading eventually to a truly low-cost system. To economically utilize space, we must first reach it with a low-cost transportation vehicle. The keys to low cost are reusability and high utilization. The present STS configuration only partly addresses reusability problems since major components are expendable or partially reusable. Similarly, high utilization concepts, in terms of payload development and cargo integration, are only beginning to be identified.

Moreover, in one respect all of the cost/benefit arguments are somewhat misleading; they divert attention from a transportation system's real purposes. The overriding issues involve what kind of space program the Nation needs. These issues--manned space flight versus automated satellite activity and space exploration versus space sciences and applications--are not new; they must be kept in mind when considering STS and the orbiter fleet size. In our opinion, given the substantial capabilities of STS, three orbiters, or certainly four at most, are sufficient to (1) perform missions representing a balanced space program and (2) allow a margin of budgetary flexibility for follow-on programs. Balancing options are available to policymakers because, generally, STS is the first manned space program which can put useful (in terms of developers and users of space-related goods and services) payloads foremost; that is, payloads based on expected scientific and applications returns, rather than spectacular, clearly visible projects based on perceived popular support. If properly managed, the shuttle can offer

extraordinary opportunities to every area of space science using free-flying satellites as well as the Spacelab. Judicious oversight should help insure that the shuttle's scientific potential is fully realized.

In perspective, U.S. space programs since Sputnik have been concerned largely with developing a manned capability in space. The STS program, selected over both a Mars landing and a space station as the major post-Apollo goal, retains manned space flight as the primary focus of NASA's budget. Almost half the shuttle's proposed payloads will involve the Spacelab. In many aspects the Spacelab, very similar to a space station, will probably be most important for studies of life-support-in-space technology. Such studies fit in with NASA's long-range plans for manned interplanetary space missions.

Hopefully, this scenario, which presents NASA's implicitly perceived thrust of national purposes in space, provides a useful framework for policy analysis. It is the role of the national political leadership, of course, to formulate national purposes in space. Over the years, most guidance to NASA has been in budgetary terms. But, because the STS era provides an opportunity for diverse and flexible space activities, national objectives should perhaps be more explicitly expressed.

RECOMMENDATION TO THE CONGRESS

The Congress should fund no more than the four orbiters presently under development and production. Consistent with this position, NASA's request for Orbiter 104 in the fiscal year 1979 budget should not be funded. Three orbiters can accommodate a substantial increase in space activity during the next decade; a fourth orbiter would provide for fleet attrition.

1976 NATIONAL MISSION MODEL

560 SHUTTLE FLIGHTS

	Fiscal year													Total U.S. Government	Total
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992		
KSC:															
NASA:													6	224	224
Spacelab	1	6	7	11	13	16	15	17	15	16	15	16	(a)	(148)	-
Space industrialization	-	2	2	2	3	3	3	3	4	4	4	4	(a)	(34)	-
Free-flying satellites	-	-	4	2	2	5	3	6	3	3	4	4	(a)	(36)	-
Other U.S. Government civil agencies:															
Free-flying satellites	-	1	-	-	-	1	-	-	1	1	1	1	-	6	6
Department of Defense:															
Free-flying satellites	1	1	7	5	8	8	7	6	8	5	7	6	2	71	71
U.S. commercial and foreign users:													3	-	106
Spacelab	-	-	-	-	1	2	2	2	2	2	3	3	(a)	-	(17)
Space manufacturing	-	-	-	2	3	4	2	4	4	5	5	5	(a)	-	(34)
Free-flying satellites	1	3	1	6	4	4	6	2	8	6	8	3	(a)	-	(52)
Total	3	13	21	28	34	43	38	40	45	42	47	42	13	301	407
VAFB:															
NASA:													2	41	41
Spacelab	-	-	-	1	2	4	4	4	4	4	4	4	(a)	(33)	-
Free-flying satellites	-	-	-	1	1	1	-	1	1	-	2	1	(a)	(8)	-
Other U.S. Government civil agencies:															
Free-flying satellites	-	-	-	1	1	2	3	2	4	2	4	2	1	22	22
Department of Defense:															
Free-flying satellites	-	-	-	1	5	5	5	3	6	5	3	4	1	38	36
U.S. commercial and foreign users:														-	21
Spacelab	-	-	-	1	1	1	1	1	1	1	1	1	-	-	(9)
Space manufacturing	-	-	-	-	-	-	1	2	2	-	-	1	-	-	(6)
Free-flying satellites	-	-	-	-	1	-	1	-	1	1	1	1	-	-	(6)
Total	-	-	-	5	11	13	15	13	19	13	15	14	4	101	122
Reflights (note b)	-	1	2	3	4	2	5	3	1	4	3	4	-	22	31
Total	3	14	21	36	49	58	58	56	65	59	64	60	15	424	560

a/Breakout of flights in 1992 not available.

b/Reflights would be required for missions not successfully accomplished because of anomalies involving the payload, vehicle, upper stage, etc.

Note: NASA updated its flight model for the FY 1979 budget submission to reflect 552 flights rather than 560 flights for a 5-orbiter fleet. A flight model of 487 flights was also prepared to reflect the capability of a 5-orbiter fleet with attrition early in the program--in effect, a 4-orbiter fleet. NASA's flight model thus varies depending on the number of operational orbiters anticipated.

APPENDIX I

1976 NATIONAL MISSION MODEL

1,091 PAYLOADS

	Fiscal year												
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	Total
U.S. Government users:													
NASA:													
Spacelab	3	16	16	30	34	40	42	43	42	42	42	42	394
Space industrialization		2	7	2	3	3	3	3	4	4	4	4	34
Free-flying satellites	4	2	6	7	7	10	13	13	12	11	12	12	111
Other U.S. Government civil agencies:													
Free-flying satellites	2	2	2	3	3	5	5	4	6	5	6	6	49
DOD:													
Free-flying satellites	23	20	23	13	28	28	18	16	23	19	17	18	246
Total--U.S. Government	32	42	53	55	75	86	81	79	87	81	81	82	834
U.S. COMMERCIAL AND FOREIGN USERS:													
Spacelab	1	3	4	6	6	10	8	11	10	11	11	11	92
Free-flying satellites	12	7	3	14	13	15	12	11	19	18	23	18	165
Total--Non-U.S. Government	13	10	7	20	19	25	20	22	29	29	34	29	257
Total	45	52	60	75	94	111	101	101	116	110	115	111	a/1091

a/Only 1,019 of these are projected for shuttle launch. The model shows 72 payloads planned for launch on expendable launch vehicles in the 1980-83 period.

Note: NASA updated its mission model for the FY 1979 budget submission to reflect 1,000 payloads rather than 1,091. The primary reductions were for U.S. commercial and foreign free-flying satellites; NASA and DOD's projected payloads changed very little.

APPENDIX I

CALCULATION OF COST ADVANTAGES OF A ONE-SITE (KSC) SHUTTLE OPERATION

A single-site STS program could save the Government from $2.3 billion to $3.5 billion, depending on the annual launch rate from KSC.

Cost Advantages of One-Site Shuttle Program

Annual launch rate from KSC	Cost savings of not modifying VAFB to accommodate shuttle operations (real-year dollars)		
	Facilities	Manpower (FY 1983-92)	Total
	---------------	(billions)	----------
40	$1.0	$2.5	$3.5
60	$0.8	$1.5	$2.3

Savings accrue from single-site operations because VAFB facilities would not be built and manpower to operate the site would not be needed. (See tables 1 and 2.) These savings, however, must be offset by the additional facilities and manpower required at KSC to handle any additional workload. Planned facilities and manpower at KSC can handle over 40 shuttle flights a year. However, additional facilities (costing about $0.2 billion--see table 3 below, note c) and manpower (costing about $1 billion--see table 4 below, note b) would be needed at KSC to support 60 or more yearly launches, thus slightly reducing overall facility savings to $0.8 billion ($1 billion minus $0.2 billion) and overall operations savings to $1.5 billion ($2.5 billion minus $1 billion). Based on present and past requirements of about 26 to 35 expendable launch vehicle flights a year, 40 shuttle launches a year is more realistic than 60; thus, KSC-only STS operations could save the Government up to $3.5 billion over the next decade. It is important to note that the $3.5 billion establishes the maximum savings due to eliminating VAFB operations. Under certain circumstances, part of the $3.5 billion savings could be realized by simply reducing the flight level of a two-site operation from 60 to 40 flights a year.

The detail and sources of the $2.3 billion to $3.5 billion potential savings are given in the following five tables.

TABLE 1

VAFB Facilities Investment
(millions of real-year dollars)

Category	
Research and development	a/$ 338.0
Support equipment	a/269.0
Communications equipment	a/44.0
Military construction	a/226.0
Total	b/877.0
Launch pad 2	c/175.7
Total	1,052.7
Costs incurred through FY 1978	d/(80.9)
VAFB facilities savings	e/$ 971.8

a/These are the estimated amounts through fiscal year 1983. The figures are as presented by DOD in the Mar. 9, 1978, hearings.

b/According to DOD's testimony, the upper bound of this estimate is $1.2 billion. Therefore, potential facilities savings could be higher than shown on this table.

c/This estimate was provided to GAO by the Air Force's Space and Missile Systems Organization.

d/See table 5.

e/This figure rounds to $1 billion.

TABLE 2

VAFB Manpower Costs (Direct and Indirect
Fiscal Years 1983-92
(millions of real-year dollars)

Fiscal year	Amount
1983	a/$ 168.5
1984	a/241.8
1985	a/258.9
1986	a/265.0
1987	a/276.6
1988	a/295.9
1989	a/316.7
1990	a/338.8
1991	a/362.5
1992	a/96.8
	$2,621.5
Minus overhead	b/(100.0)
	c/$2,521.5

a/The source of these costs is the "Space/Shuttle Preliminary Cost Data Base," dated June 1977, prepared by the Operations Resources Analysis Office, Johnson Space Center. The figures were given in FY 1975 dollars; we converted them to real-year dollars, using an annual inflation factor of 7 percent. The source document contained the following introductory comments: "The resources data contained within this document covers all those costs and associated manpower (direct and indirect) to provide the standard Shuttle services * * * for the current STS Flight Traffic Model."

b/According to NASA Headquarters and DOD headquarters officials, the manpower estimates for VAFB include about $100 million of overhead costs which may not disappear if shuttle operations do not materialize at VAFB.

c/This rounds to $2.5 billion.

TABLE 3

Single-Site Shuttle Program:
Additional Facility Costs at KSC if Launch
Rate Increases from 40 Flights a Year to 60 Flights
(millions of real-year dollars)

Shuttle research and development:	
Launch processing system	
Equipment	
Equipment surcharge for non-Government-furnished equipment	
Site activation	
Design support	
Total	$ 69
Payload research and development:	
Ground support equipment	
Launch processing system	
Design support	
Total	24
Construction of facilities:	
Mobile launch platform 3	
SRB disassembly workstands	
Orbiter processing facility	
Total	a/88
Additional mobile launch:	
Platform 4	25
Other:	
Program ground support equipment	
Spares	
Propellants	
Payload support	
Shop capability	
Total	b/40
Total	c/$246

a/Present planning, which anticipates 40 flights a year at KSC, calls for 3 mobile launch platforms. Therefore this figure ($88 million) is overstated by $25 million.

b/We disagree with these costs; they appear to be operations costs which would not represent "additional" facility costs associated with single-site operations.

c/This total and the detailed breakdown given above were provided to us by Mission Analysis and Integration, NASA Headquarters; adjusted per notes a and b is $181 million, which rounds to $0.2 billion.

TABLE 4

Single-Site Shuttle Program:
Additional Manpower Costs at KSC if Launch
Rate Increases from 40 Flights a Year to 60 Flights
(millions of real-year dollars)

Fiscal year	Amount
1983	a/$ 282.6
1984	a/277.7
1985	a/297.2
1986	a/318.0
1987	a/340.2
1988	a/364.0
1989	a/389.5
1990	a/416.8
1991	a/446.0
1992	a/122.7
	$3,254.7
	b/x 30%
	$ 976.4

a/The source of these costs is the "Space/Shuttle Preliminary Cost Data Base," dated June 1977, prepared by the Operations Resources Analysis Office, Johnson Space Center.

b/KSC, as currently planned will support 40 shuttle flights a year. Based on discussions with officials at NASA Headquarters, Johnson Space Center, and KSC, apparently no studies have been made of how much additional manpower would be required at KSC to support up to 60 shuttle flights a year (a 50-percent increase in the currently planned flight activity). However, Johnson Space Center and KSC representatives have commented informally that any increase in manpower requirements would be minimal but could approach 30 percent. On March 30, 1978, officials in NASA Headquarters Space Transportation System Operations Office stated that 60 launches a year from KSC might require slightly more than a 30-percent increase in the proposed shuttle manpower level at KSC. However, as stated above, this information was not based on any detailed evaluation.

TABLE 5

VAFB Facilities Costs
Incurred through FY 1978
(millions of real-year dollars)

Category	Prior years	FY 1978	Total through FY 1978
Research and development	$31.2	$24.3	$55.5
Support equipment	-	17.2	17.2
Communications equipment	-	8.2	8.2
Military construction	-	-	-
Total	$31.2	$49.7	$80.9

Note: The figures are as presented by DOD in the Mar. 9, 1978, hearings.

SHUTTLE PERFORMANCE CAPABILITY FOR NORTHERLY LAUNCHES FROM KSC (assuming initial launch ascent azimuths of 8, 10, 13, and 19 degrees, with a subsequent dogleg maneuver to obtain a 98-degree, 150-nautical-mile orbit)

Mission/operating profile	Weight-carrying capability (pounds) at various launch azimuths (note a)			
	(degrees)			
	8	10	13	19
Basic deployment and retrieval (note b)	27,499	26,089	23,725	18,306
Less: Management reserve (note c)	1,270	1,270	1,270	1,270
Total	26,229	24,819	22,455	17,036
Add: Capability gained by				
--offloading SRB recovery system (note d)	1,259	1,259	1,259	1,259
--deploying but not retrieving on same mission (note e)	7,434	7,434	7,434	7,434
Total (note f)	34,922	33,512	31,148	25,729

a/Weight-carrying capability decreases as the various launch azimuths (angle measured from true north to the direction of the ascent ground track of the launch vehicle) increase because the shuttle requires a dogleg maneuver to achieve a 98-degree inclination orbit (angle at which the orbit crosses the Earth's equator). For example, a 13-degree azimuth would place the shuttle in a 74-degree inclination orbit. To achieve a more northerly inclination (such as 98 degrees) from this same azimuth, an in-flight direction change maneuver (requiring additional energy) must be performed. Therefore, more northerly launch azimuths (8 degrees and 10 degrees) require less direction change and result in greater weight-carrying capability.

b/This basic deployment/retrieval capability is in reference to DOD's heaviest or most demanding mission. The mission calls for a 32,000-pound delivery capability to a 98-degree inclination, 150-nautical-mile orbit, plus a retrieval capability of 25,000 pounds from the same orbit. As presently planned, the deployment/retrieval mission will require a four-person crew, 7 days in space, and full fuel for the Reaction Control System

and the Orbital Maneuvering System. Under the ground rules discussed above, a KSC-launched shuttle cannot meet the reference mission of 32,000 pounds delivery/25,000 pounds retrieval. For example, the performance at an 8-degree launch azimuth is 27,499 pounds delivery/25,000 pounds retrieval. However, by adjusting the mission/operating profile (see notes d and e), it is possible to achieve a 32,000-pound delivery capability. Achieving the 32,000-pound delivery does result in not having same-flight retrieval capability for this mission. We feel this is an acceptable trade-off because DOD plans only two missions a year involving delivery weights greater than 22,000 pounds.

c/This management reserve is part of the shuttle's overall payload-carrying capability; however, NASA management holds 1,270 pounds aside in reserve status to cushion the effects of unforeseen system weight anomolies.

d/The SRBs will separate from the shuttle system at an altitude of about 150,000 feet. After separation, the boosters will parachute into the ocean some 150 nautical miles down range for recovery and reuse. Deleting this recovery system (parachutes, etc.) increases the weight-carrying capability by 1,259 pounds. This means that for DOD's two missions a year, the boosters will not be reusable after splash down and may require salvage operations. As a result, NASA has estimated that each of these missions will have an additional cost of $8 million over the 12-year shuttle era (1980-91). However, this cost could be kept extremely low or be eliminated altogether because the growth versions of DOD's heavy payloads are not expected until after 1985. By that time many recovered/reworked boosters should be available. With proper planning, these boosters having limited remaining launch lives could be used for the few missions under consideration.

e/Missions calling for satellite delivery and retrieval on one flight require more fuel, time, and crew than do delivery-only missions. The latter category of missions has the following requirements.

Two less crew members and 3 fewer days in space	1,179
One less cryogenic tank set	1,608
No rendezvous radar	337
Less Orbital Maneuvering System fuel	936
Less Reaction Control System fuel	3,374
	7,434 pounds

Although these performance figures were reconciled by NASA and DOD on several occasions, NASA officials stated during the latter part of March 1978 that the capability was in error. They said that capability gained by deploying but not retrieving on the same mission was overstated by 1,050 pounds; that is, the figure should be 6,384 and not 7,434. We have not analyzed this new data. None of the adjustments indicated above will adversely affect abort procedures or compromise orbiter and crew safety.

f/These totals and the preceding figures were agreed to during a reconciliation meeting on March 17, 1978, attended by headquarters' representatives from NASA, DOD, and GAO. It was also agreed that, depending on the needs of the specific mission, certain manifest items, such as the galley, can be offloaded to give several hundred pounds additional weight-carrying capability. None of these offloaded items will adversely affect abort procedures or compromise orbiter and crew safety.

Furthermore, emphasis should be given to the fact that performance capability is a dynamic or flexible concept. For example, NASA's Jupiter Orbiter Probe mission was initially thought to exceed the system's weight-carrying capability by 8,000 pounds. Now, NASA engineers tentatively expect the mission to be easily accommodated and, in fact, have available capability for an additional 5,000 pounds--giving a total performance improvement of 13,000 pounds. Most of these improvements are reflected in the capability figures cited earlier; however, the figures do not recognize the relatively (compared to VAFB) favorable wind conditions at KSC. Depending on the actual winds at time of launch, additional performance capability (from 750 to 2,100 pounds) may be available. Additional capability and flexibility may ultimately be available because NASA has underway several studies involving ways to modify the shuttle's design to give additional performance capability ranging from 2,000 to 20,000 pounds. One study involves attaching additional solid rocket motors to the ET; another involves adding a catalyst to the SRB propellant. Both studies, being designed specifically to provide payload enhancement for occasional performance-demanding missions, would have minimum impact on overall shuttle design. The performance studies were initiated by NASA's Associate Administrator for Space Transportation Systems and were targeted for completion in June 1978.

ESTIMATED COSTS TO U.S. GOVERNMENT (note a)

for 1980-92 OPERATIONS IN SPACE (note b)

		(billions)	
PAYLOADS (note c):			
NASA:			
Spacelab (note d)	$ 4.7		
Space Industrialization (note e)	13.7		
Free-flying satellites	10.8	$29.2	
Other U.S. Government civil agencies:			
Free-flying satellites	2.6	2.6	
Department of Defense:			
(not provided) (note f)	-	-	
Total payloads			$31.8
TRANSPORTATION (note g):			
Standard services (note h):			
Spacelab	9.3		
Space Industrialization	1.4		
Free-flying satellites	5.5		
Projected reflights (note i)	0.9	17.1	
Optional services (note j):			
Spacelab hardware usage	2.5		
Upper stages	1.7	4.2	
Total transportation			21.3
Total			$53.1

a/Costs shown were provided by NASA and were not verified or analyzed in depth by us. All costs are expressed in real-year dollars.

b/See app. I for projected shuttle flights and payloads during the FY 1980-92 period.

c/Payload costs include development of the experiment/mission, procurement of mission spacecraft and scientific hardware, and subsequent analysis of data derived from the mission.

d/Spacelab is discussed at length in ch. 3.

e/According to NASA this program includes activities ranging from materials processing in space to constructing large structures in space. It should be noted that, although relatively few shuttle flights are shown, the Space Industrialization program represents a large part of the mission model's total payload cost.

f/DOD would not provide the estimated costs of its payloads projected for the 1980-92 period because of the data's sensitivity.

g/Transportation costs shown are for shuttle flights only, although 83 expendable launch vehicles are projected for use during the shuttle era. Most of these vehicles will be flown while users are transitioning to the shuttle. The remainder provides a backup posture for launching critical satellites in the event of a shuttle anomoly. NASA and DOD have estimated the costs for these 83 vehicles to be about $3 billion.

h/Standard shuttle transportation services include such support as two standard mission destinations (28.5-degree and 56-degree orbit inclinations), a 1-day mission duration, orbiter flight-planning services, a three-person flight crew (commander, pilot, and mission specialist), and onorbit payload handling. Additional (optional) services are explained in note j.

i/A total of 560 shuttle flights are projected; 31 of these, however, are for reflights of missions not successfully accomplished. Mission failure may result from such occurrences as shuttle cargo bay doors failing to open, upper propulsion stage failing to ignite, satellite not checking out properly before deployment, and shuttle failure causing return to Earth before mission accomplishment.

j/Optional shuttle transportation services will, in many cases, be required to tailor flights to the user's needs. Optional services include such items as use of Spacelab hardware, revisit and retrieval of satellites, use of upper stages, additional time on orbit, payload data processing, and use of extra fuel to take the orbiter to an altitude higher than 160 nautical miles. The estimated costs for these services, however, were provided for only two items--Spacelab hardware usage and upper stages.

APPENDIX V

NASA's PROCUREMENT STRATEGY FOR A FIVE-ORBITER FLEET (note a)

Orbiter designation	Estimated costs of procurement/modification (note b) (millions)	Status/comments
101	(a)	This development vehicle (the Enterprise) was used for approach and landing tests in 1977; however, it is not fully engineered for operations. NASA does not plan for Orbiter 101 to be part of the four-orbiter shuttle fleet referred to in the President's fiscal year 1979 budget request.
102	$28.0	This development vehicle will be used for the first manned orbital flight in mid-1979. After six orbital test flights, the vehicle will require only minor modifications to become fully operational.
Structural test article (Orbiter 099)	$596.6	Originally intended to be used for structural tests only, the test article will be upgraded to operational capability. Some equipment from Orbiter 101, such as crew module and avionics, will be used to help minimize the cost of upgrading. This vehicle is planned to be operational in February 1981.
103	$801.7	This will be the first vehicle built entirely with production funds. Fabrication and assembly of primary structures will continue in fiscal year 1979 and detail parts fabrication for secondary structures will start. The planned delivery date for this vehicle is September 1982.
104	$851.6	Essentially no funds have been expended for this vehicle. The fiscal year 1979 budget request includes about $20 million which will be used to procure long-lead materials and begin fabrication. Orbiter 104's scheduled delivery date is September 1984.

a/The present administration has decided to support a four-orbiter fleet, with consideration for a fifth in future years in the event that projected flight rates, or the accidental loss of an orbiter warrant such action. NASA has not decided whether the optional or future orbiter will be (1) Orbiter 101, modified for orbital flight capability, or (2) a wholly new vehicle, to be procured after Orbiter 104. Depending on when work begins, modification of Orbiter 101 would cost $500 million or more.

b/To operate four orbiters, ground support equipment costing about $230 million will be required. The cost of this equipment is not allocated to individual orbiters.

NASA

National Aeronautics and
Space Administration

Washington D C
20546

Office of the Administrator

FEB 15 1978

Honorable Elmer B. Staats
Comptroller General of the
United States
General Accounting Office
Washington, DC 20548

Dear Mr. Staats:

I appreciate the opportunity afforded NASA to provide comments on GAO's draft of a proposed report on the "Space Transportation System: An Analysis of Launch Site and Fleet Size Requirements." We have had interchange with your staff regarding the report and a number of differences in view or fact have been resolved. However, major disagreements still remain, particularly, the issue regarding a single Space Shuttle launch site operation at the Kennedy Space Center.

I am seriously concerned that the report, as drafted, will not provide to the Congress the proper perspective of the essentiality and value of east and west coast launch site operations, or the relationship of orbiter fleet size and launch sites to national payload program options and users' budgets. Therefore, I believe it is important that the matters as set forth in this letter be included in your report to Congress. I understand that the Department of Defense, the Department of State and the Office of Management and Budget also have concerns regarding the draft report and are providing comments.

The NASA, on a continuing basis, develops several levels of national space payload program activity based on consolidation of NASA payload objectives and program planning with similar projections furnished by the civil community and the Department of Defense. These projections are the most reasonable expectation of both on-going and new programs which would evolve in an environment of continued dependence upon space in support of our national goals.

An analysis of fleet capabilities and economics as related to projected national payload activity and comparisons to alternate operational scenarios lead to significant findings which are contrary to the conclusions of the report:

- first, NASA, DOD, State Department, and the OMB agree that overflight of the continental U.S., Canada and the Soviet Union by high inclination Space Shuttle flights is clearly unacceptable. We cannot base our national space capability on the expectation that overflight might be approved sometime in the future, nor accept the risk that, if approved, it could be terminated suddenly due to international complications or unacceptable hazards to people in areas of increasing population density.

  [GAO comment: Land overflight and international implications are discussed on pp. 11 to 17 and 20 to 24 respectively.]

  Moreover, there are current and projected high priority DOD payloads which cannot, from a performance standpoint, be launched from KSC even with an overflight waiver. Therefore, any alternatives proposed for the national program must provide for Space Shuttle or ELV (expendable launch vehicles) launches from VAFB.

  [GAO comment: A KSC-launched shuttle would have the performance capability to accommodate high priority DOD payloads as shown on pp. 17 to 19. Limited shuttle facilities or ELVs at VAFB would not be required.]

- second, even assuming that overflight could be a... the GAO estimate of savings of $2.7 to $3.8 billi... for the several single Shuttle site alternatives proposed is overstated.

  [GAO comment: These figures were contained in our draft report. As presented on p. 9, they have been revised to a possible saving of $2.3 billion to $3.5 billion, depending on the flight rate from KSC.]

[See GAO note, p. 58.]

Alternately, the presumption that no decision on overflight from KSC will occur until a sufficient number of Space Shuttle flights have been completed imposes severe cost penalties. If a decision on VAFB Space Shuttle facilities were to be delayed until 1985, the cost increase for the case where overflight is allowed is about $1.25 billion while the cost increase for the case where overflight is denied and there is a 1985 go-ahead on the VAFB Space Shuttle facility is estimated to be $2.8 billion. It is clear that waiting until 1985 to decide on overflight restrictions is not a viable alternative in supporting our national space activity because of the high cost impacts.

[GAO comment. We have never suggested that a decision on VAFB be delayed until 1985. As shown on p. 15, what we have suggested is that the STS will have had over 3 years' launch experience (entailing over 50 flights) from KSC by June 1983, when the second launch site is scheduled to become operational. These flights should provide a sufficient shakedown period in which problems will be identified and corrected. There will be no need for VAFB STS facilities if the shuttle is as operationally reliable as expected. If this level of reliability is not achieved, the entire program could be in jeopardy.]

third, a four or five orbiter fleet operating from both east and west coast launch sites is more cost effective than any Orbiter/ELV mix for supporting projected payload traffic over a wide range of activity levels. This finding was demonstrated in the "Joint NASA/USAF Study on Space Shuttle Orbiter Procurement and Related Issues" prepared in support of the 1978 budget decision and was confirmed in a comprehensive reassessment of fleet capabilities and payload and traffic projections completed this fall by the NASA and DOD. In the FY 1979 budget, the President's decision was to proceed with a four-orbiter fleet operating from two sites with an option that can be exercised in the early 1980 time frame for additional orbiters to accommodate increased traffic requirements or the loss of an orbiter. This posture provides a sound planning base for all users to proceed with payload transition to the Space Shuttle and the phase-out of expendable launch vehicles.

NASA strongly disagrees with the GAO opinion that three orbiters can provide ample support for the national space activity and still have unneeded capacity. There are already firm commitments for 23 Space Shuttle flights through January 1982 and discussions are currently underway with over ten additional users desiring launches in 1981-1982.

[GAO comment: As shown on pp. 33 to 37, a three-orbiter fleet can provide a balanced and viable space program which is an increase over past activity. A four-orbiter fleet would provide a cushion for attrition. It is not economical to invest in unneeded capacity.]

Finally, I cannot understand how GAO can disregard the collective judgements of the experts from NASA, DOD and other user elements as to future requirements in space <u>and</u> suggest to the Congress that GAO's estimate of "foreseeable needs" has some higher order of credibility.

[GAO comment: During our study of the fleet size issue, we obtained data and comments from NASA, DOD, and other user elements, including leading researchers and academicians in the space science community. These views were fully considered in our analysis.]

- <u>fourth</u>, our studies show that the payload program content can vary significantly among users and types of programs without altering the fleet size conclusion. Therefore, the fleet size decision does not set the size of the national space program nor the budget levels of individual users, and the Congress will continue to exercise its annual evaluation of individual space programs.

[GAO comment: As reflected on pp. 33 to 37, we believe the fleet size issue will have an impact on the size of future space activity.]

In summary, the NASA data and analyses show that the requirement for a VAFB Space Shuttle site is national in nature and based on firm performance requirements and sound economic benefits. An adequate Shuttle fleet to serve all users--civil and military--will provide the assured launch capability necessary to promote early transition by all users and to permit phase-out of expendable launch vehicles--actions which provide important economic benefits.

Decisions made now on the Space Transportation System will establish the future level of this nation's space capability for many years. The issues and alternatives are complex and the stakes are high--scientific and technological leadership, national security, and international prestige. Moving forward now with an adequate orbiter fleet/two site operation will enhance this nation's posture in space and provide a means for taking full advantage of new opportunities in the future exploitation of space.

Very truly yours,

A. M. Lovelace
for
Robert A. Frosch
Administrator

GAO note: The deleted comments relate to matters in the draft report which have been revised or omitted from this final report.

THE UNDER SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

RESEARCH AND ENGINEERING

17 FEB 1978

Mr. R. W. Gutmann
Director, Procurement and
Systems Acquisition Division
United States General Accounting Office
Washington, D. C. 20548

Dear Mr. Gutmann:

This is in reply to your letter to the Secretary of Defense regarding your draft report dated January 1978, on the "Space Transportation System: An Analysis of Launch Site and Fleet Size Requirements," OSD Case #4788, Code 952181.

The Department of Defense strongly disagrees with your recommendation that the Congress should not fund Vandenberg Air Force Base (VAFB) modifications to accommodate the Shuttle.

The report does not fully recognize that, to the extent the Shuttle is used to launch military payloads, it is a part of our military capability. The DoD has extensive plans to use the Space Transportation System with its new capabilities when it becomes operational. In the early 1980s we plan to start to transition all of our spacecraft from launch on current boosters to the Shuttle and to begin the phaseout of our current expendable boosters. Shuttle launches will be required from Kennedy Space Center (KSC) for spacecraft which must be placed in low and medium inclination, high altitude orbits. VAFB is essential for Shuttle launch of DoD spacecraft which must be placed in very high inclination (polar, near polar) low altitude orbits.

The spacecraft which we will launch on the Shuttle from VAFB include our heaviest spacecraft which support missions of highest national priority. These spacecraft flown on the Shuttle will be improved growth versions of operational spacecraft now being launched from VAFB. We now are using the full 24,300 lb TITAN IIID payload delivery capability from VAFB, and are fully depending on the 32,000 lb Shuttle delivery capability from VAFB by the mid-1980s. Your report suggests that if range safety constraints are waived at KSC, the Shuttle flying north over the continental U.S. could deliver 25,000 lbs to low polar orbit. Your report also states that this capability is adequate for DoD. In fact, the standard Shuttle payload capability is only 22,000 lbs under these conditions (98^{o} inclination and 150 nmi). We are aware that it may be possible to increase Shuttle performance by several hundred pounds on certain flights

without significant risk by off-loading some items from the Shuttle flight manifest. If the Shuttle is configured to deliver a payload but not retrieve an old satellite on the same flight, performance might be increased to perhaps 25,000 lbs. However, from these Shuttle performance figures, we must deduct the weight of a cradle to properly support our payload in the Shuttle - about 2500 lbs. The resulting performance is less than that of current boosters and is totally unacceptable for the mid-1980 period.

[GAO comment: A 25,000-pound capability was cited in our draft report; the figure was updated after additional review and analysis. As shown on pp. 17 to 19, a KSC-launched shuttle has the capability to launch even the heaviest DOD payloads to their desired orbits.]

Further, we cannot ignore the fact that northerly high inclination Shuttle launches ascending over the Soviet Union, even with prior notification, will be disconcerting and perhaps objectionable to the Soviets. No matter how sophisticated the Soviet radars, the similarity of such northerly Shuttle launches to potential U.S. ICBM launches can lead to adverse Soviet reactions, if done routinely. Under worst case conditions, such as Shuttle breakup during ascent, a severe Soviet response cannot be discounted. Finally, the northerly launch from KSC to polar orbits entails possible casualty expectations (significant risk to life and property) over the U.S. and Canada greater than now considered acceptable.

[GAO comment: International implications and casualty expectations associated with KSC-only shuttle operations are discussed on pp. 20 to 24 and 11 to 15, respectively.]

DoD interest in the Shuttle centers around the new capabilities offered which can lead to more effective military space operations. We believe that our VAFB launched payloads are of highest national priority and are most likely to benefit from these new capabilities. DoD utilization of the Shuttle's most attractive capabilities will be denied if the VAFB Shuttle launch capability is not provided.

Attached are more detailed comments. Data presented in these comments are consistent with that provided previously to your examiners.

Sincerely,

William J. Perry

Attachment

COMMENTS

[See GAO note 1, p. 66.]

Page ii, line 19. Launch azimuths of 13° can overcome the first two constraints (sonic boom, and solid rocket splashdown); but overflight of heavily populated U.S. areas during Shuttle ascent to orbit poses severe problems. Casualty expectations would be greater than is acceptable today over the continental United States. However, the principal arguments against use of KSC for high inclination launches are Shuttle performance degradation to an unacceptable level, and launch over the Soviet Union. Nevertheless, land overflight risks cannot be ignored.

[See GAO note 2, p. 66.]

[GAO comment: As shown on pp. 17 to 19, a KSC-launched shuttle has the capability to launch even the heaviest DOD payloads to their desired orbits. International implications and casualty expectations associated with KSC-only shuttle operations are discussed on pp. 20 to 24 and 11 to 15, respectively.]

[See GAO note 1, p. 66.]

Page iii, line 21. As stated in the basic letter, DoD requires the full capability attainable by using the Shuttle from VAFB for polar launches. The payloads involved exist and are of high priority. They are not prospective in nature. Additionally, while DoD is a strong proponent of having a Shuttle launch and landing facility at VAFB, the civil community should also benefit greatly.

[See GAO note 2, p. 66.]

[GAO comment: As shown on pp. 17 to 19, a KSC-launched shuttle has the capability to launch even the heaviest DOD payloads to their desired orbits.]

Page VI, line 23. DoD disagrees with the conclusion that one launch site can meet all foreseeable needs.

[See GAO note 2, p. 66.]

[GAO comment: As shown on pp. 17 to 19, a KSC-launched shuttle has the capability to launch even the heaviest DOD payloads to their desired orbits.]

[See GAO note 1, p. 66.]

Page 14. The need for a Shuttle launch facility at VAFB is a national need. While DoD will certainly benefit from a Shuttle capability at VAFB which will permit full exploitation of the Shuttle's new capabilities, DoD is not the only beneficiary. DoD has no desire to have its own "ballpark," and this GAO statement indicates a lack of understanding of the importance of polar orbits to civil users. [See GAO note 2, p. 66.]

[GAO comment: GAO recognizes the importance of polar orbits to civil users. It is GAO's position that these orbits can be accomplished from KSC as shown on pp. 17 to 19.]

[See GAO note 1, p. 66.]

Page 14, line 27. Degradation of Shuttle payload delivery capability is a primary DoD concern regarding KSC launches to polar orbit as noted in the basic letter. These degradations in Shuttle performance result from the need to minimize sonic boom on launch to an acceptable level over populated areas, and the desire to drop the solid motors in relatively deep water so that they can be reused. Even neglecting the sonic boom and motor recovery considerations, the range safety problems associated with polar launches from KSC are formidable. Shuttle trajectories north over the U.S. would result in casualty expectations above those currently considered acceptable for space launches. The concern cannot be dismissed lightly. DoD believes that such risks to the U.S. civil population are probably unacceptable.

[See GAO note 2, p. 66.]

[GAO comment: Although NASA has not assigned a specific numerical reliability factor to the shuttle, based on extensive knowledge and experience gained from space and aircraft programs, it expects the shuttle to be fully reliable. Contractor studies have continually cited a reliability factor of 0.9999 in risk assessment studies. Given this degree of reliability shuttle overflight of land may pose fewer problems than do commercial airlines. For a complete discussion of casualty expectations associated with KSC-only shuttle operations, see pp. 11 to 15.]

[See GAO note 1, p. 66.]

Page 16, line 10. DoD does not support the casualty expectation figures provided in the GAO report. The apparent source of these values was an analysis performed in 1969. The data has not been updated since.

[See GAO note 2, p. 66.]

[GAO comment: The casualty expectations for the space shuttle and Titan vehicles were extracted from a 1976 and a 1977 study, respectively. The values are the most current data available.]

[See GAO note 1, p. 66.]

Page 20, line 2. As noted in the basic letter, the Shuttle launched from KSC can deliver only about 22,000 lbs to a 98° inclination, 150 nmi orbit. We are aware that it may be possible to increase Shuttle performance above this standard figure by several hundred pounds on certain flights without significant risk by off-loading some items from the Shuttle flight manifest. Also by configuring the Shuttle to deliver but not retrieve a given payload, performance might be increased to perhaps 25,000 lbs. However, from these Shuttle performance figures we must deduct the weight of a cradle to properly support our payload in the Shuttle - about 2500 lbs. Further, some orbiters may be overweight and deliver 1500 to 2500 lbs less payload than the standard configuration. The resulting performance is less than TITAN IIID can deliver today and is an unacceptable payload delivery capability for the mid-1980s.

[See GAO note 2, p. 66.]

[GAO comment: As shown on pp. 17 to 19, a KSC-launched shuttle has the capability to launch even the heaviest DOD payloads to their desired orbit.]

Page 20, line 14. While a number of DoD spacecraft launched now on Scout and Atlas F boosters from VAFB are in the 2,000 lbs or lighter weight category, our major, highest priority spacecraft fully use the 24,300 lb delivery capability of TITAN IIID. A Shuttle launched northerly at KSC would not be able to deliver these heavy payloads to the desired orbit. Planned growth in payload capability over the next decade will require the full Shuttle capability from VAFB (32,000 lbs). [See GAO note 2, p. 66.]

[GAO comment: See preceding GAO comment.]

Page 22, "Other Considerations." By denying the military image of the Shuttle, the report inappropriately dismisses the State Department concerns over polar launches from KSC which have extensive overflight over not only the U.S. and Canada, but the USSR and China on the initial orbit. We believe there are plausible reasons why such extensive routine first orbit overflights of the central USSR could trigger undesirable Soviet reactions. Soviet reactions would not necessarily be mitigated by notification procedures under the "Measures Treaty." Such northerly Shuttle launches might appear to the Soviets deceptively similar to ICBM launches. Also, there are accidents that, while very unlikely (e.g., breakup of the External Tank), could confuse Soviet radars and in a worst case, increase the risk of a severe Soviet response.

[See GAO note 2, p. 66.]

[GAO comment: Although any factor which contributes to the possibility of nuclear war should never be treated lightly, the shuttle is an international program of cooperation and will be even more so during the operational phase. If high inclination KSC launches do raise a radar misinterpretation issue, we feel that resolution efforts through multilateral cooperation should be exhausted before spending large amounts on VAFB. For a full discussion on international implications, see pp. 20 to 24.]

GAO notes:

1. The deleted comments relate to matters in the draft report which have been revised or omitted from this final report.

2. Page number references cited in the agency letters relate to our draft report and will not correspond to pages of this report.

APPENDIX VIII

ASSISTANT SECRETARY OF STATE
OCEANS AND INTERNATIONAL ENVIRONMENTAL AND SCIENTIFIC AFFAIRS
WASHINGTON, D.C. 20520

February 28, 1978

Mr. J. K. Fasick
Director, International Division
United States General Accounting Office
Washington, D.C. 20548

Dear Mr. Fasick:

Thank you for your letter of January 5, 1978 concerning comments on the draft of your report on "Space Transportation System: An Analysis of Launch Site and Fleet Size Requirements." We have discussed this matter with Mr. Joe W. Johnson of your organization but feel it desirable to forward our remarks in writing.

We commented in detail on your proposal by our letter of November 11, 1977 to Mr. Conahan of GAO. Seven important factors relating to the impact of your proposal on US foreign policy were discussed. Your report, however, did not reflect these concerns. For example, the anticipated sensitivity of Canada to launches over their populated regions is ignored. In light of the recent COSMOS 954 incident and the initiatives being taken by Canada in the United Nations regarding possible hazards from space launches, their reaction is likely to be strong. In addition, your report greatly understates the importance of the 1971 "Agreement on Measures to Reduce the Risk of Outbreak of Nuclear War between the United States of America and the Union of Soviet Socialist Republics" and the spirit in which that agreement was negotiated and concluded.

Enclosed are further detailed comments on the draft report, which we respectfully request you take into account in the final report. They are confined to the question of launch site and do not deal with the matter of fleet size.

Very truly yours,

PATSY T. MINK
Assistant Secretary

Enclosure:

Detailed Comments

Detailed Comments on Draft Report

p.ii, L.15: The potential cost savings cited are not well supported. The reason for the range in values is not given.

[See GAO note 2, p. 71.]

[GAO comment: The potential cost savings range in value from $2.3 billion to $3.5 billion. The reason for this range and the support for these figures are shown on pp. 9 and 10.]

p.ii, bottom of the page: Payload penalties inflicted by changes in trajectory should be noted.

[See GAO note 2, p. 71.]

[GAO comment: To accomplish northerly launches from KSC to polar and near-polar orbits, the space shuttle must change its launch trajectory in flight, a maneuver which requires additional energy and reduces the payload weight-carrying capability. However, a KSC-based STS can accommodate all of the payloads, civil and military, projected for the 1980-91 period, including the missions projected for high inclination orbits. For a complete discussion of this matter, see pp. 17 to 19 and app. III.]

p.iv, L.8-11: This characterization of the foreign policy concerns of the Department is neither objective nor accurate.

[See GAO note 2, p. 71.]

[GAO comment: We state that, although the Department of State has expressed several concerns about high inclination launches from KSC, we think most of these reasons are substantially insufficient to preclude such launches. Some of these concerns, such as land overflight and payload weight-carrying capability, were also raised by NASA and DOD and have been adequately discussed. However, we do recognize, and so state, that one of the Department of State's concerns, the possibility of adverse Soviet reaction, is difficult to conclusively assess because it involves essentially unquantifiable national security and foreign policy considerations. We believe further congressional inquiry may be needed to determine if this concern is sufficiently serious to justify spending up to $3.5 billion to construct and operate a second STS site. (See pp. 20 to 21.]

pp.8-11: This discussion is argumentative and presumes the STS was not justified in the first place. The report should be able to focus on the specific issues to be treated and should strive for a more objective presentation.

[See GAO note 2, p. 71.]

[GAO comment: We believe ch. 1 of our report presents a fair and objective history of events and decisions leading up to the current decisions facing the Congress concerning the number of space shuttle launch and landing sites needed and the number of orbiters needed. We believe this information is essential to put our findings as well as the current decision before the Congress in the proper perspective.]

[See GAO note 1, p. 71.]

p.20, L.1-4: These figures differ from those given to us by the Department of Defense and NASA.

[See GAO note 2, p. 71.]

[GAO comment: The current positions of GAO, NASA, and DOD regarding the payload weight-carrying capability of a northerly launched space shuttle from KSC are presented on pp. 17 to 19.]

p.20,L.11-12: We suggest that the different opinions of NASA and the Department of Defense concerning sufficiency of KSC payload capability be referenced.

[See GAO note 2, p. 71.]

[GAO comment: As shown on pp. 17 to 19, a KSC-launched shuttle has the capability to launch even the heaviest DOD payloads to their desired orbits.]

[See GAO note 1, p. 71.]

p.22, L.21-25: We continue to be informed by the technical agencies involved that your assertions of payload adequacy are not accurate.

[See GAO note 2, p. 71.]

[GAO comment: As stated above, see pp. 17 to 19.]

p.23, L.1: This discussion ignores the anticipated sensitivity of Canada to launches over their populated regions. The launch phase is the most hazardous portion of a mission and, in light of the recent COSMOS 954 incident, their reaction could be strong.

[See GAO note 2, p. 71.]

[GAO comment: A discussion of international implications and casualty expectations is presented on pp. 20 to 24 and pp. 11 to 15, respectively.]

p.23, L.5 from bottom: The capability of Soviet detection and discrimination systems should be explored further.

[See GAO note 2, p. 71.]

[GAO comment: In an earlier comment we recognized that those areas dealing with possible adverse Soviet reaction are difficult to conclusively assess because they involve unquantifiable national security and foreign policy considerations. We believe further congressional inquiry may be needed to determine if this concern is sufficiently serious to justify the VAFB site.]

p.24. The entire discussion presented on the matter of the 1971 "Measures Agreement" is faulty and misleading. Your readers should be cautioned that your interpretation is not authoritative and should not be construed as the US position on the matter.

[See GAO note 2, p. 71.]

[GAO comment: We have stated the Department of State's position on p. 21 that launching north from KSC would be inconsistent with the spirit and intent of the above-cited 1971 agreement.]

p.24: Our letter of November 11, 1977 is relevant.

[See GAO note 2, p. 71.]

[GAO comment: The applicable portion of the Department of State's November 11, 1977, letter is included on page 20.]

[See GAO note 1, p. 71.]

p.24, L.21-25: The mission agencies should be consulted on the question of notification. It may be improvident to assume that n tification is possible or practicable.

[See GAO note 2.]

[GAO comment: Even with two STS sites, prior announcement of shuttle flights will be required to clear ocean areas for SRB splash down.]

[See GAO note 1.]

The report contains material some of which may be considered classified by the Executive Branch.

[GAO comment: Information in this report was obtained from unclassified sources and the draft has been reviewed by DOD.]

GAO notes:

1. The deleted comments relate to matters in the draft report which have been revised or omitted from this final report.

2. Page number references cited in the agency letters relate to our draft report and will not correspond to pages of this report.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

MAR 8 1978

Mr. Victor L. Lowe
Director
General Government Division
United States General Accounting Office
Washington, D. C. 20548

Dear Mr. Lowe:

Thank you for providing the Office of Management and Budget the opportunity to comment on your January 1978 draft report, "Space Transportation System: An Analysis of Launch Site and Fleet Size Requirements." Although I would defer to the appropriate operating agencies for substantive comments on many of the specific points made in your report, I do have strong reservations about the policy implications of your recommendation to confine shuttle launches solely to an east coast site. This suggestion, if implemented, would, I feel undermine the "national" character of this program, possibly resulting in dual Defense and civilian space transportation vehicles for many years to come.

With regard to the number of orbiters, funds to proceed with the production of a four-orbiter fleet are provided in the NASA budget for FY 1979. This number is considered sufficient to meet both civilian and military requirements. Funding for additional orbiters can be considered, however, if projected flight rates or the loss of an orbiter warrant future augmentation of this fleet.

In terms of your recommendation on launch sites, limiting the shuttle program to the Kennedy Space Center (KSC) could have serious consequencies for satisfying critical national defense requirements. First, range safety concerns as well as potential repercussions resulting from high inclination shuttle launches ascending over the Soviet Union would make any decision to use KSC for polar launches highly unlikely. Moreover, even if such a choice were made, reduced payloads and little capacity for growth would effectively preclude DOD from launching selected satellites from this site. Finally, the advantages offered civilian users through west coast launches would also be lost under your proposed arrangement.

[GAO comment: Range safety, international and performance implications of KSC-only shuttle operations are discussed on pp. 11 to 15, 20 to 24, and 17 to 19, respectively.]

In light of these considerations, we urge that you reconsider your recommendation for a single launch site for the shuttle program. As you note on page 37 of your report, "the STS must be a national program meeting civil and defense needs." Only with the two sites can this goal be effectively achieved.

Sincerely,

Jim McIntyre

James T. McIntyre
Acting Director

cc:
Honorable Robert A. Frosch, Administrator,
National Aeronautics and Space Administration
Honorable Harold Brown, Secretary,
Department of Defense
Honorable Cyrus R. Vance, Secretary,
Department of State

PREVIOUS GAO

SPACE TRANSPORTATION SYSTEM REPORTS

June 2, 1972	Cost Benefit Analysis Used in Support of the Space Shuttle Program (B-173677)
June 1, 1973	Analysis of Cost Estimates for the Shuttle and Two Alternate Programs (B-173677)
June 1974	Space Transportation System Staff Study
February 1975	Space Transportation System Staff Study
April 21, 1976	Status and Issues Relating to the Space Transportation System (PSAD-76-73)
May 27, 1977	Space Transportation System: Past, Present, Future (PSAD-77-113)

PRINCIPAL OFFICIALS RESPONSIBLE FOR ACTIVITIES DISCUSSED IN THIS REPORT

	Tenure of office	
	From	To
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION		
ADMINISTRATOR:		
Robert A. Frosch	June 1977	Present
Alan M. Lovelace (acting)	May 1977	June 1977
James C. Fletcher	Apr. 1971	May 1977
George M. Low (acting)	Sept. 1970	Apr. 1971
Thomas O. Paine	Apr. 1969	Sept. 1970
DEPARTMENT OF DEFENSE		
SECRETARY OF DEFENSE:		
Harold Brown	Jan. 1977	Present
Donald H. Rumsfeld	Nov. 1975	Jan. 1977
James R. Schlesinger	June 1973	Nov. 1975
William P. Clements (acting)	May 1973	June 1973
Elliot L. Richardson	Jan. 1973	Apr. 1973
Melvin R. Laird	Jan. 1969	Jan. 1973
DEPARTMENT OF THE AIR FORCE		
SECRETARY OF THE AIR FORCE:		
John C. Stetson	Apr. 1977	Present
Thomas C. Reed	Jan. 1976	Apr. 1977
James W. Plummer (acting)	Nov. 1975	Dec. 1975
John L. McLucas	July 1973	Nov. 1975
John L. McLucas (acting)	May 1973	July 1973
Dr. Robert C. Seamans, Jr.	Feb. 1969	May 1973

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